A, U, K,

EMU SERIES

Electron Microscope

INSTRUCTION BOOK

RCA

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or
Jim Campbell

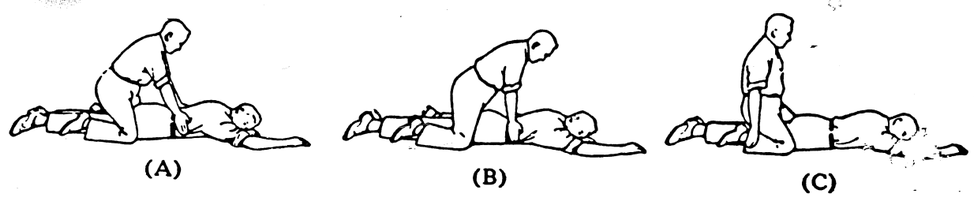
WARNING

THE VOLTAGES EMPLOYED IN THIS EQUIPMENT ARE SUFFICIENTLY HIGH TO ENDANGER HUMAN LIFE AND EVERY REASONABLE PRECAUTION HAS BEEN OBSERVED IN DESIGN TO SAFEGUARD THE OPERATING PERSONNEL. AN IMPORTANT PART OF THE PROTECTIVE SYSTEM IS THE SERIES OF DOOR INTERLOCK SWITCHES AND ANY TAMPERING WITH THESE SWITCHES SHOULD BE PROHIBITED. THE POWER SHOULD BE REMOVED COMPLETELY BEFORE CHANGING TUBES OR MAKING INTERNAL ADJUSTMENTS.

FIRST AID IN CASE OF ELECTRIC SHOCK

1. PROTECT YOURSELF with dry insulating material.
2. BREAK THE CIRCUIT by opening the power switch or by pulling the victim free of the live conductor.

   DON'T TOUCH VICTIM WITH YOUR BARE HANDS until the circuit is broken.



(A) (B) (C)

3. LAY PATIENT ON STOMACH, one arm extended, the other arm bent at elbow. Turn face outward resting on hand or forearm.
4. REMOVE FALSE TEETH, TOBACCO OR GUM from patient's mouth.
5. KNEEL STRADDLING PATIENT'S THIGHS. See (A).
6. PLACE PALMS OF YOUR HANDS ON PATIENT'S BACK with little fingers just touching the lowest ribs.
7. WITH ARMS STRAIGHT, SWING FORWARD gradually bringing the weight of your body to bear upon the patient. See (B).
8. SWING BACKWARD IMMEDIATELY to relieve the pressure. See (C).
9. AFTER TWO SECONDS, SWING FORWARD AGAIN. Repeat twelve to fifteen times per minute.
10. WHILE ARTIFICIAL RESPIRATION IS CONTINUED, HAVE SOMEONE ELSE:
    (a) Loosen patient's clothing.
    (b) Send for doctor.
    (c) Keep patient warm.
11. IF PATIENT STOPS BREATHING, CONTINUE ARTIFICIAL RESPIRATION. Four hours or more may be required.
12. DO NOT GIVE LIQUIDS UNTIL PATIENT IS CONSCIOUS.

EMU-SERIES
ELECTRON MICROSCOPES

INTRODUCTION.

This book is a reprint, under a single cover, of the following instruction literature:

Reference	Subject
IB-39008-2	EMU-series Electron Microscope (covering Models EMU-1, EMU-2, and EMU-2A)
IB-39008-2S1	Electron Microscope EMU-2B
IB-39008-2S2	Electron Microscope EMU-2C and Extended-range Lens Kit MI-12929
IB-39008-2S3	Electron Microscope EMU-2D and Compensated Pole Piece MI-12932

VARIOUS MODELS OF THE EMU-SERIES.

The main differences between models of the EMU-series electron microscopes affect particularly the following features of these instruments:

EMU-1, -2, -2A	mechanical valve system
EMU-2B	electromechanical (solenoid) valve system
EMU-2C	similar to EMU-2B but includes also: extended-range lens self-bias gun magnetic alignment of electron beam
EMU-2D	similar to EMU-2C but includes also: compensated objective pole piece new projector pole piece aperture

CHANGES TO INSTRUCTION BOOKS.

The changes listed below should be made to the instruction book and supplements printed herewith. These are designated by their publication number (IB-39008-2, IB-39008-2S1, IB-39008-2S2, IB-39008-2S3) which appears in the lower right-hand corner of the title page of each publication.

CHANGES TO INSTRUCTION BOOK IB-39008-2.

Page 10, Figure 7: a later version of this drawing is printed herewith.

Page 45:

Following "V-12, Thermocouple Gauge", add:
Stock No. 47745, Gasket for V-12, Dwg. No. 613792-59

Under heading "INTERMEDIATE VIEWING SCREEN HOUSING", change the sixth item (Window, Intermediate Viewing Screen) as follows: Stock No. 47129 to read 59206; Dwg. No. 870447-1 to read 870447-1 sub 4.

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Printed in U.S.A.

IB-39008-3

Under same heading, change the seventh item (Aperture, Objective Pole Piece) as follows: Stock No. 49022 to read 56112; Dwg. No. 886416-1 to read 886416-1 sub 4.

Under same heading, fourth item from bottom of page (Screen, Intermediate Viewing), change Stock No. 47749 to read 54935, and Dwg. No. 878488-1 to read 878521-2.

Page 49:

Under heading "H.V. UNIT ASSEMBLY" change C-44 capacitor Stock No. 47937 to read 57490, and Dwg. No. 504425-501 to read 8899337-1.

Under heading "ELECTRON GUN" change Filament Assembly Stock No. 44511 to read 93789, and add Dwg. No. 8835425-1.

Page 50:

Under heading "ELECTRON GUN" delete entire item: Shield, Stock No. 48108, Dwg. No. 859392-1; and substitute: Assembly, Stock No. 56710, Dwg. No. 427468-501.

Under same heading, add the following items:
Primary viewing screen, Stock No. 54943, Dwg. No. 890308-1
Aperture for primary viewing screen, Stock No. 54934, Dwg. No. 878521-1.

Under heading "DIFFRACTION UNIT" change Window, Stock No. 47129 to read 59206, and Dwg. No. 870447-1 to read 879447-1 sub 4.

Page 51:

Under heading "STAGE ASSEMBLY" add the following item:
Gasket, felt, Stock No. 56163, Dwg. No. 897600-1.

Under heading "VIEWING CHAMBER ASSEMBLY" change Window, Stock No. 48006 to read 59207; do not change Dwg. No. 878320-1.

Under heading "PHOTO CHAMBER ASSEMBLY" add the following items at end of listing:
Cassette less cover, Stock No. 93579, Dwg. No. 427219-501 less Pts 3 and 4.
Cassette cover only, Stock No. 93669, Dwg. No. 878356-501.

Page 53:

Under heading "OIL DIFFUSION PUMP" add the following items:
Octoil, 115-cc can, Stock No. 45924
Silicone fluid, 200-cc can, Stock No. 54857

Page 77:

In Figure 47 change Window gasket, Stock No. 47745 to read 48012; and delete Stock No. 48006 for Window, viewing chamber.

CHANGES TO SUPPLEMENT IB-39008-2S1.

Page 1, sub-paragraph a, change "lower left-side" to read "lower right-side".

CHANGES TO SUPPLEMENT IB-39008-2S2.

Page 9:

After last item listed under heading "ELECTRON GUN, SELF-BIAS" add:
Connector for filament lead, Stock No. 95662, Dwg. No. 99087-1.

Page 12:

Under heading "HIGH VOLTAGE BUSHING", change capacitor C46 Stock No. 53017 to read 53107.

Page 15:

Under heading "BATTERY BOX" change stock and drawing numbers for batteries B9 and B11 as follows:
B9, Stock No. 47215, Battery 22 1/2 volts, Dwg. No. RCA-VS131
B11, Stock No. 47214, Battery 22 1/2 volts, Dwg. No. RCA-VS102

CHANGES TO SUPPLEMENT IB-39008-2S3.

Add the following items to the List of Replaceable Parts:

Stock No.	Description	Drawing No.
94521	Lower diaphragm	8835438-1
94522	Snap ring	8835437-1
94523	Upper diaphragm	8835436-1

NOTE ON ELECTRON MICROSCOPE EMU-2D.

The List of Replaceable Parts for the Electron Microscope EMU-2D consists of the Lists of Replaceable Parts published in Instruction Book Supplements IB-39008-2S2 and IB-39008-2S3 with the following modifications.

Page 11 of IB-39008-2S2:

Under heading "LOWER CHASSIS 302945-503" change R3 to read: R3, Stock No, 28414, Resistor 25,000 ohms, 1 watt, Dwg. No. 878435-44.

Under same heading, delete R62.

Under same heading change R20 to read: R20, Stock No. 46060, Resistor 20,000 ohms, 50 watt, Dwg. No. 449695-10.

Under same heading add new part: R136, Resistor 10,000 ohms, 10 watt, Stock No. 51869, Dwg. No. 878435-19.

Page 10 of IB-39008-2S2:

Under heading "TOP CHASSIS ASSEMBLY 613728-502" add R62, Stock No. 513410, Resistor 0.1 meg, 1 watt, Dwg. No. 727836-86.

Under same heading change C22 to read: C22, Stock No. 58911, Capacitor 0.027 mfd, 1200 volts, Dwg. No. 728656-157.

The schematic diagram for the Electron Microscope EMU-2C as printed in Supplement IB-39008-2S2, applies to the EMU-2D after the changes listed above have been incorporated. Note that resistor R62 was connected across resistor R3 and is now connected between ground and terminal X39-6 of resistor R37. Also note that the added resistor R136 is connected between the plate pin 3 and cathode pin 8 of V7/X22 in the 370-volt regulated supply circuit.

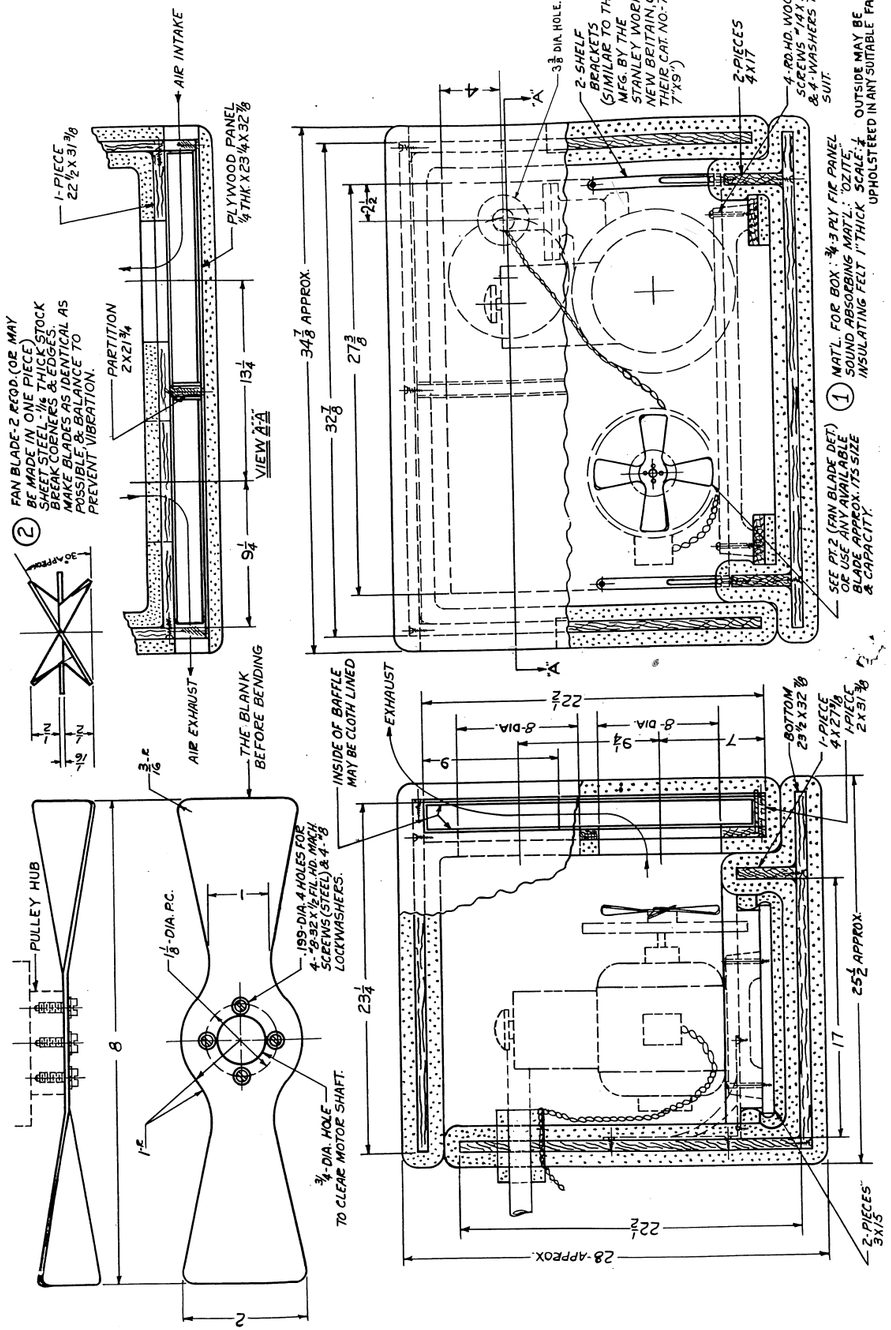

Figure 7. Noise Suppressor for Rotary Pumps (PX-277149 sub 3)

RCA ELECTRON MICROSCOPE, TYPE EMU-2B
SUPPLEMENT TO
EMU-SERIES INSTRUCTION BOOK (IB-39008-2)

DISPOSITION: To be inserted in Instruction Book IB-39008-2

The RCA Electron Microscope, Type EMU-2B, is essentially the same as the Type EMU-2A, as described in Instruction Book IB-39008-2, except that it is provided with a magnetic valving system. This new system takes the place and functions of the mechanically operated valving system used in the earlier instruments.

EQUIPMENT

The RCA Electron Microscope, Type EMU-2B, complete with associated equipment, is identified as follows:

Designation	Power Required	Items		Quan.
MI-12951-J	115 volts a-c, 60 cycles single phase	Electron Microscope EMU-2B	MI-12957-C	1
		Vacuum Pump	MI-12956H	1
		Voltage Stabilizer	MI-12959	1
		Accessory Kit	MI-12980-F	1
		Instruction Book	IB-39008-2	2
		Instruction Book	IB-39008-2S1	2
MI-12951-K	230 volts a-c, 50 cycles, single phase	Electron Microscope EMU-2B	MI-12957-C	1
		Vacuum Pump	MI-12956-K	1
		Voltage Stabilizer	MI-12959-A	1
		Accessory Kit	MI-12980-F	1
		Instruction Book	IB-39008-2	2
		Instruction Book	IB-39008-2S1	2
MI-12951-L	115 volts a-c, 50 cycles, single phase	Electron Microscope EMU-2B	MI-12957-C	1
		Vacuum Pump	MI-12956-K	1
		Voltage Stabilizer	MI-12959-B	1
		Accessory Kit	MI-12980-F	1
		Instruction Book	IB-39008-2	2
		Instruction Book	IB-39008-2S1	2

DESCRIPTION

As stated in the introductory paragraph of this Supplement, the Type EMU-2B Electron Microscope differs from the Type EMU-2A in that a magnetically controlled valve system is used instead of the mechanically operated valve system of the earlier equipment. The new magnetic valve system takes the place of the mechanical valve block and its operating crank handle which are described on page 11 and in Figures 6B, 65, and 66 of the EMU-Series Instruction Book.

The magnetic valve system includes the following items.

a. A power supply unit, which is energized from a standard 115-volt, 50/60 cycle, alternating-current source, and supplies current to the four valve-operating solenoids. This unit is installed in the lower left-side compartment of the Electron Microscope cabinet, below the low-voltage chassis.

b. A three-valve solenoid mechanism (valves A, B, D), which is mounted on the top of the power supply unit and is connected, through flexible tubings, to the mechanical pump and vacuum chamber. A rubber hose connection is also made to the dehydrator bottle. The thermocouple gauge for measuring the fore pressure is mounted on the base of the three-valve block.

c. A one-valve block (valve C), installed between the diffusion pump and the vacuum enclosure. (The corresponding sides of the valve block are marked DP and VE, respectively.)

d. A three-position control switch, through which the valves are operated in proper sequence. This switch is located on the panel at the right side of the microscope column.

The four valves are respectively marked A, B, C, D, and their functional locations within the vacuum system are as shown in the vacuum system schematic layout, Figure 6A (page 8) of the

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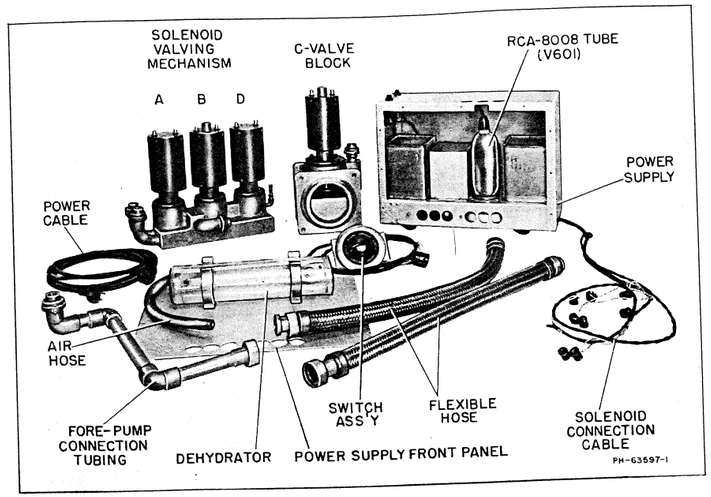

Figure 1—Magnetic Valve System, Component Parts

EMU-Series Instruction Book. They are operated electrically through the control switch, the three positions of which correspond to the following operating conditions:

a. "LOADING" position: Valves B and C are closed, valves A and D are open. The vacuum chamber is cut off from both pumps and communicates with the atmosphere through the dehydrator.

b. "PREPUMP" position: Valves A and D close, then valve B opens; valve C remains closed. The vacuum chamber is connected to the fore pump for "rough" pumping.

c. "OPERATE" position: Valve B closes, then valves A and C open; valve D remains closed. The vacuum chamber is connected to the diffusion pump, which is connected in series with the fore pump. This position is used for obtaining high vacuum (i. e., lower pressure than can be obtained with the fore pump alone).

ELECTRICAL CIRCUIT DESCRIPTION—The circuit schematic diagram for the Type EMU-2B

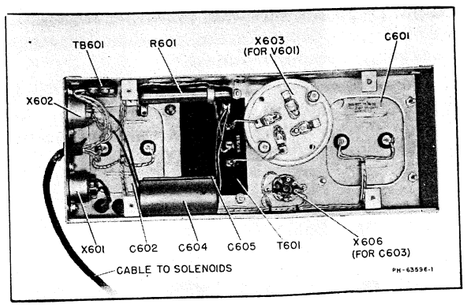

Figure 2—Magnetic Valve System Power Supply Unit, Bottom View

Electron Microscope differs from that shown for the Type EMU-2A in Figure 71B of the EMU-Series Instruction Book in that the valve interlock switch S-6 is done away with; and terminals J19-1, J19-8 are connected to terminals 1 and 2 of terminal board TB-601 of the magnetic valve solenoid power supply unit.

The schematic diagram of this power supply unit is shown in Figure 3 of this Supplement. Through the power cable and connector X-601, a-c power is applied at 115 volts, 50/60 cycles, to the primary of transformer T-601, which is protected by two 3-ampere line fuses (F-601, F-602). The secondary of T-601 supplies heating current (7.5 amperes at 5 volts) to the filament of the rectifier diode V-601. Closing of the switch S-601 (located at the top of the power supply unit) connects the plate circuit of this rectifier tube across the 115-volt a-c line. Rectified (d-c) current is then supplied by the tube to the valve-operating solenoids through a smoothing filter network made up of shunt capacitors C-601, C-602, C-603 and series resistor R-601. Through plug and jack connectors X-602, J-601 and the control switch S-602 the four solenoids K-601, K-602, K-603, K-604 are selectively connected into and out of the circuit. The solenoids actuate, respectively, valves A, B, C, D in the order mentioned. The valve positions corresponding to the three switch positions were listed in a previous paragraph.

INSTALLATION

The installation procedure is the same as described for the Type EMU-2A Electron Microscope on pages 21 and 22 of the EMU-Series Instruction Book. The fore pump intake should be connected to the tubing assembly that is brought out through an opening at the bottom rear of the microscope cabinet (the other end of this tubing assembly is attached to the base of the three-valve

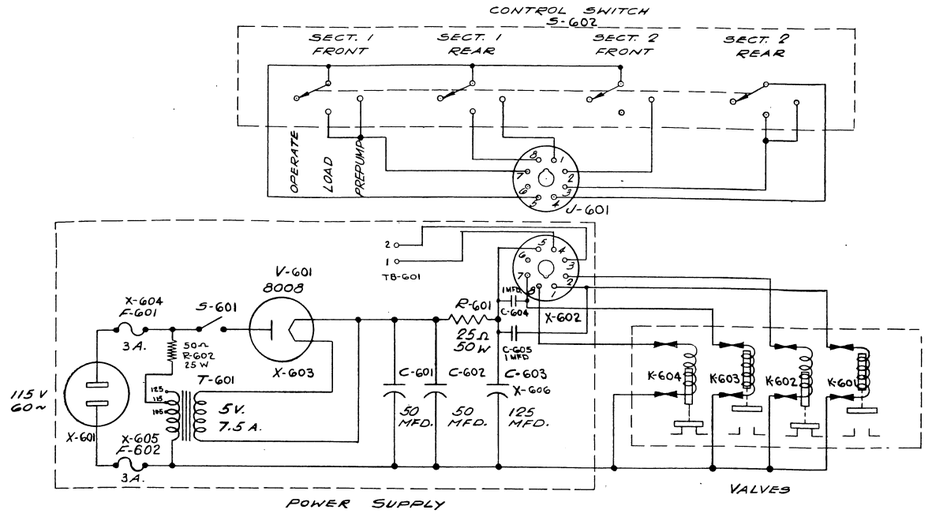

Figure 3—Magnetic Valve System Power Supply Unit, Circuit Schematic Diagram (M-443564—sub 3)

block). The connection to the fore pump should be as short as possible, in order to utilize the fullest capabilities of the valving system. It is recommended that a metal hose line or copper tubing be employed, so that shortest pumping time and lowest ultimate pressure may be obtained.

The type RCA-8008 rectifier tube (V-601) in the magnetic valve power supply unit is shipped in place in its socket. To check that it is firmly seated and that its plate connection cap is properly engaged over the terminal on the top of the tube, the front panel of the power supply unit may be temporarily lifted off after unscrewing the nine screws that hold it in place.

The primary of the power transformer (T-601) n this same power supply unit is provided with three taps for a-c input voltages of 105, 115, and 125 volts, respectively. Connection should be made to the tap that corresponds most closely to the actual supply voltage available for energizing the equipment.

OPERATION

a. Initial Operation—When operating the equipment for the first time (or after installation of a new RCA-8008 rectifier tube in the solenoid power supply unit), check that the toggle switch on the top of the power supply unit is in the "OFF" position. Then plug the power cord of the power supply unit into a nearby 115-volt, 50/60 cycle a-c supply outlet. This energizes the power supply unit, to which power should remain applied for twenty to thirty minutes. Following this period, the equipment is ready for normal, routine operation, as described in the following paragraph.

b. Routine Operation—The principles underlying routine operation of the EMU-2B Electron Microscope are essentially the same as described in the Instruction Book IB-39008-2, except for details of the procedure for evacuating the microscope column. In this connection, steps 1 through 7 of the procedure entitled "Obtaining Beam and Image," given on page 24 of the instruction book should be changed to read as follows:

1. Check that the "MAIN POWER" and "HIGH VOLTAGE" toggle switches are in the "OFF" (left) position. Check that the toggle switch on the top of the solenoid power supply unit is in the "OFF" position.

2. Throw the "PANEL LIGHTS" toggle switch "ON" (right). The position of the "ROOM LIGHTS" switch is optional.

3. Turn the valve control, located on the right-side front panel, to the "OPERATE" position.

4. Turn on the power to the line voltage stabilizer and fore pump. Plug the power cord of the solenoid power supply unit into a nearby 115-volt, 50/60-cycle a-c supply outlet. After 30 seconds throw the toggle switch on the top of the power supply unit to the "ON" position. Close both cabinet doors and check that the top hood is down.

5. The diffusion pump will take ten to twenty minutes to begin pumping. During this time, the "FORE PRESSURE" meter indication will first rise, and then decrease slightly as the diffusion pump warms up. The "COLUMN PRESSURE" meter indication will rise to a maximum reading when the diffusion pump begins pumping. At this time, the glow around one of the electrodes of the vacuum indicator lamp will be extinguished. Further heating of the diffusion pump will cause the "COLUMN PRESSURE" meter indication to decrease.

Steps 6 and 7, page 24 of the instruction book, are to be deleted.

Steps 8 to 14 describe the balance of the procedure.

NOTE: At the end of the day or working period, the toggle switch on the top of the solenoid power supply unit should be placed in the "OFF" position. The valve control switch may be left in the "OPERATE" position.

REPLACEMENT PARTS LIST

The replacement parts for the RCA Electron Microscope, Type EMU-2B, are the same as those for the Type EMU-2A, as listed in the Instruction Book IB-39008-2, pages 45 to 54, inclusive, except for the following changes, additions, and deletions.

MAIN ASSEMBLY: Delete the four items of "Dial Assembly" and change the following item to read:

Symbol No.	Stock No.	Description	Drawing No.
A-6	54932	Clock	443531-1

Add the following items:

Stock No.	Description	Drawing No.
54934	Aperture, condenser (pri. screen)	878521-1
54935	Aperture, projection (int. screen)	878521-2
54943	Screen, primary viewing	890308-1

UPPER CONTROL PANEL ASSEMBLY: Change C-15 and add S-6 as indicated below:

Symbol No.	Stock No.	Description	Drawing No.
C-15	70620	Capacitor, 1.0 mfd., 200 v.	72086-111
S-6	55407	Switch, valve control	443553-1

LOWER CONTROL PANEL: Change the following items as shown:

Symbol No.	Stock No.	Description	Drawing No.
M-1	46028	Meter, fore pressure	430501-1
M-2, M-3	46030	Meter, column pressure and beam	430501-2
M-4	46032	Meter, test	430501-3

TOP CHASSIS ASSEMBLY: Change the following items as shown:

Symbol No.	Stock No.	Description	Drawing No.
C-17	70638	Capacitor, 0.1 mfd., 600 v.	72086-228
C-18 to C-20	70620	Capacitor, 1.0 mfd., 200 v.	72086-111
C-21	70615	Capacitor, 0.05 mfd., 400 v.	72086-166
C-22	70654	Capacitor, 0.025 mfd., 1000 v.	72086-283
C-32	70627	Capacitor, 0.005 mfd., 600 v.	72086-217
C-33	Same as C-17		
C-34	70640	Capacitor, 0.5 mfd., 200 v.	72086-230
C-35	70638	Capacitor, 0.1 mfd., 600 v.	72086-228
C-36	70638	Capacitor, 0.1 mfd., 600 v.	72086-228
C-37	70641	Capacitor, 1.0 mfd., 200 v.	72086-231
C-38, C-39	Same as C-36		
C-40	39652	Capacitor, 0.001 mfd., 500 v.	727866-147
C-41	68908	Capacitor, 0.006 mfd., 500 v.	727866-165
C-42	Same as C-17		
R-51	30651	Resistor, 270,000 ohms, ½ w.	727834-91

BOTTOM CHASSIS ASSEMBLY: Make the following changes:

Symbol No.	Stock No.	Description	Drawing No.
C-12	54346	Capacitor, 0.001 mfd., 500 v.	727866-147
C-13	70638	Capacitor, 0.1 mfd., 600 v.	72086-228
C-16	70620	Capacitor, 1.0 mfd., 200 v.	72086-111
R-8	48182	Resistor, 75,000 ohms, 1 w.	896199-1
R-62	48181	Resistor, 80,000 ohms, 1 w.	896199-2
T-1	46047	Transformer	891390-1

POWER SUPPLY FOR SOLENOID VALVING SYSTEM FOR EMU-2B: These items are not used in the EMU-1, EMU-2, EMU-2A, which utilize a mechanically operated valving system. For the EMU-2B Electron Microscope, which incorporates the magnetic, solenoid-operated valving system, the following Power Supply Unit replacement parts are available:

Symbol No.	Stock No.	Description	Drawing No.
C-601, C-602	55406	Capacitor, 50 mfd., 165 v. a.c.	8882234-1
C-603	48159	Capacitor, 125 mfd., 350 v.	86060-6
C-604, C-605	70621	Capacitor, 1 mfd., 400 v.	72086-141
F-601, F-602	10907	Fuse, 3-amp.	55544-4
R-601	46328	Resistor, wire wound, fixed, 25 ohms, 50 w.	427491-29
R-602	53838	Resistor, 50 ohms, 25 w.	427491-34
S-601	48904	Switch, toggle, valve power, "ON-OFF"	878368-5
T-601	55408	Transformer, filament	900979-501
X-601	55410	Connector, 2-contact, female, for W-17, power input	8882232-1
X-602	55409	Connector, 8-contact, male, to valve-control switch	8882233-1
X-603	44755	Socket, rectifier tube	429151-1
X-604, X-605	45851	Holder, fuse	844027-2
X-606	31319	Socket, capacitor, for C-46	87156-3

SOLENOID VALVE ASSEMBLY: The following replacement parts are for use in the EMU-2B Electron Microscope only:

Stock No.	Description	Drawing No.
55703	Coil, solenoid coil assembly, "A," "B," "C," "D" valves	887198-501
55678	Gasket, plunger, 11/16" dia., 3/16" hole, "B" and "D" valves	8887199-1
55679	Gasket, plunger tube, 1-1/16" dia., 27/32" hole	8887199-2
48715	Gasket, valve assembly to valve block, "A," "B" and "D" valves	613792-76
48655	Gasket, valve assembly to column, "C" valve	613792-78
53633	Gasket, vacuum, line fitting	613792-88
55680	Gasket, "A," "B" and "D" valve; rubber, ⅞" dia., ⅜" hole	8887199-4
55681	Gasket, "C" valve, 2-5/16" dia., ⅜" hole	8887199-3
55744	Spring, "A" valve plunger	8888434-2
55793	Spring, "C" valve plunger	8888434-1
55745	Spring, "B" and "D" valve plunger	8888433-1

H. V. UNIT ASSEMBLY: Change the following part:

Symbol No.	Stock No.	Description	Drawing No.
C-31	54535	Capacitor, fixed, paper, 1.0 mfd., 600 v., removable footed mtg.	981040-4

SPECIMEN CHAMBER ASSEMBLY: Delete the Micrometer screw spring, Stock No. 48386, Drawing No. 718995-13. Add the following part:

Stock No.	Description	Drawing No.
48010	Spring, micrometer screw	718955-13

STAGE ASSEMBLY: Delete the packing, pushrods, Stock No. 46999, Drawing No. 878391-2.

VALVING MECHANISM: Delete all items under this heading, as this mechanism is not used in the EMU-2B Electron Microscope.

BATTERY BOX (for Cabinet): Add the following item:

Symbol No.	Stock No.	Description	Drawing No.
X-47	18007	Socket	844041-503

CABLES AND CONDUCTORS: Change Stock No., Description, and Drawing No. for cable W-7 and add items J-15, J-31, and J-32 as listed below:

Symbol No.	Stock No.	Description	Drawing No.
W-7	55033	Cable, thermocouple to bottom chassis	427481-502
J-15	35354	Connector, female, for cable W-7	413691-9
J-31	35354	Connector, 8-contact, female, for valve control cable	413691-9
J-32	48924	Connector, 2-contact, female, for valve power supply cable	891356-2

MISCELLANEOUS MATERIAL AND PARTS: Delete items with stock numbers 44218, 45924, 46605, 48388. Add the following items:

Stock No.	Description	Drawing No.
54857	Fluid, diffusion pump (200 cc. bottle)	8858084-2
53766	Dehydrator, less Drierite crystals	427422-502

ELECTRON MICROSCOPE, TYPE EMU-2C
and
EXTENDED RANGE LENS KIT MI-12929
FOR TYPE EMU ELECTRON MICROSCOPES

SUPPLEMENT TO INSTRUCTION BOOK IB-39008-2

SPOSITION: To be supplied with Instruction Book IB-39008-2 and Supplement IB-39008-2S1.

e type EMU-2C Electron Microscope described in this Supplement is an im-
oved version of the Type EMU-2B. Information and instructions given for the
IU-2B instrument in instruction book IB-39008-2 and supplement IB-39008-2S1
ly also to the new EMU-2C instrument, except as described in the present
pplement IB-39008-2S2. A section at the end of the present supplement also
ntains instructions for installing an Extended Range Lens Kit (MI-12929) on
rlier EMU Electron Microscopes to provide them with this feature and its at-
dant more flexible operation.

ELECTRON MICROSCOPE, TYPE EMU-2C

UIPMENT SUPPLIED.

e Type EMU-2C Electron Microscope with associated equipment is supplied
der either one of two schedule references, ES-12951-M and ES-12951-N, as
lows:

signation	Power Supply	Description	RCA Reference	Quan.
-12951-M	115 volts a-c 60 cycles, single phase	EMU-2C Electron Microscope Vacuum Pump Voltage Stabilizer	MI-12957-D MI-12956-H MI-12959	1 1 1
-12951-N	115 volts a-c 50 cycles, single phase	EMU-2C Electron Microscope Vacuum Pump Voltage Stabilizer	MI-12957-D MI-12956-K MI-12959	1 1 1

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While the vacuum pump and the voltage stabilizer are as described in the EMU-Series instruction book, the Type EMU-2C Electron Microscope differs from the Type EMU-2B described in that instruction book (IB-39008-2) and its supplement (IB-39008-2S1). Briefly, the new features of the Type EMU-2C, not present in the Type EMU-2B, include the following:

a. Self-bias electron gun
b. Magnetic alignment of the electron beam
c. Extended-range intermediate lens
d. Use of lead glass in the diffraction chamber windows.

These various features are discussed in the following paragraphs in conjunction with the schematic diagram E-309860 appended to this Supplement.

SELF-BIAS ELECTRON GUN.

The electron gun of the EMU-2C instrument differs electrically from that of the earlier EMU-2B instruments described on pages 4 and 5 of the instruction book in that the electron gun aperture (cathode shield or grid cap) of the EMU-2C is biased with respect to the filament instead of being at the same potential as this. For this purpose a resistor, R128, shunted by a capacitor, C46, is inserted in the grid cap circuit, as shown in the new schematic diagram. These two circuit components are mounted within the high-voltage bushing.

The zero-bias and self-bias guns are interchangeable. Each attaches to the instrument with the same screws. However, the alignment provisions described on page 5 of the instruction book, lines 11 to 24 of left-hand column, are replaced in the EMU-2C instrument by a new magnetic alignment coil and anode assembly described in a later paragraph of this Supplement.

The self-bias gun is mounted in the instrument so that the plane of the pins is parallel to the front of the microscope. The filament leads from the bushing are connected to the pins of the gun. The spade tip is attached under one of the gun hold-down screws.

When a zero-bias gun is to be used in place of the self-bias gun, one filament clip is attached to the center pin of the gun. The spade tip is screwed down under one of the gun hold-down screws; and the other filament clip is attached to the wire prong which rises from the rear of the spade tip.

FILAMENT ADJUSTMENT. - The filament adjustment procedure described in the EMU-Series instruction book, IB-39008-2, pages 37 and 38 applies only to the zero-bias gun. For the self-bias gun the procedure is as follows:

The filament is centered with respect to the grid cap aperture in much the same manner as in the zero-bias gun. When the filament tip is off-center in a direction perpendicular to the filament plane, it should be gently bent into place. To correct centering errors in the plane of the filament, unscrew the cap and change the angle of the filament support disc.

The height of the filament from the grid cap is not critical. Differences in height produce differences in beam current: to increase this current, decrease the filament height by screwing the cap on further; to reduce the current, increase the filament height by unscrewing the cap as required. A wide range of beam currents is thus obtainable, but the general practice is to operate at currents between 200 and 350 microamperes.

Starting with the tip of the filament flush with the surface of the grid cap, turn the cap counterclockwise (looking at the cap) six turns. Place the filament height gauge (RCA drawing reference 3858031) so that the small rod enters the grid cap aperture. Connect an ohmmeter or other continuity tester for measurement between a filament pin and the body of the electron gun. Turn the grid cap until point of continuity is shown. The filament height is then .180 inch, which is satisfactory for most operation. If desired, beam current may be increased or decreased by turning the cap in or out, respectively, an amount determined by experiment. In such experiments, turn the cap in small steps of one-third turn at a time.

CAUTION

When using the self-bias gun, do not turn the filament emission (beam control) much higher than that point where beam current or image brightness ceases to change rapidly with increase in emission. Unnecessarily high emission reduces filament life. On the other hand, do not operate with a filament emission lower than the point just mentioned, because then the energy distribution of the electron beam is not as suitable for microscopy work.

MAGNETIC ALIGNMENT OF ELECTRON BEAM.

Alignment of the electron beam, in the EMU-2B instrument, is accomplished by mechanical means through the tilt-adjustment and lateral-adjustment screws provided in the anode assembly on which the electron gun assembly is mounted (see Figures 19, 20, 21 of the instruction book, and lines 11 to 24, page 5, left-hand column).

In the EMU-2C microscope a combination of mechanical and electrical means is used for the beam alignment. For this purpose, a new anode assembly takes the place of the one used in the EMU-2B and earlier equipments. The assembly is located between the electron gun and condenser lens sections of the instrument and does not include any primary viewing screen or screen window.

The new assembly includes four coils placed around the path of the electron beam, with their magnetic axes in a horizontal plane and intersecting on the center line of the microscope column. The coils are mounted in a support casting which may be displaced laterally through two alignment thumbscrews. These screws are used for rough mechanical alignment of the beam, such as is required after installation of a new electron-gun filament.

Electrically, the coils form two parallel-connected pairs. Each pair is shunted by a potentiometer, R129, R130, which permits adjustment of the current in the respective coils. These potentiometers are operated by the RIGHT-HAND ALIGNMENT and LEFT-HAND ALIGNMENT knobs on the control panel. These controls are used for fine alignment of the beam. They move the beam in two mutually perpendicular directions.

ALIGNMENT PROCEDURE. - The alignment procedure for the EMU-2C Electron Microscope differs from that given for the earlier instruments on pages 24, 25, and Figure 10 of instruction book IB-39008-2. The following procedure should therefore be substituted and is given under the assumption that all parts of the instrument have been thoroughly cleaned and properly mounted.

1. Place the valve control in the LOADING position to admit air into the column, cut off all electric power to the instrument, and remove the front hood, or cover, to gain access to the microscope column. Check that objective and projector pole pieces are in place in their respective lenses, but remove the objective aperture. By visual inspection, adjust gun and lens alignment screws so that the entire column appears centered. Insert a test specimen (carbon black or magnesium oxide) into the specimen chamber.

2. Throw on power, evacuate the column, and obtain the electron beam, as described in the instruction book, IB-39008-2 page 24, and supplement IB-39008-2S1. Set the MAGNIFICATION control to 1.

3. Set the INTENSITY control to maximum current and turn the R. H. ALIGNMENT and L. H. ALIGNMENT controls to their center positions. Then operate the electron-gun adjusting screws to obtain illumination of the final viewing screen.

Turn down the INTENSITY control while observing the final viewing screen. ıe illumination will be reduced and a shadow will appear on the screen. Re- ore the illumination by operating the R. H. ALIGNMENT and L. H. ALIGN- ENT controls. Continue the process until the INTENSITY control can be ried from maximum to one-half maximum positions without losing illumina- ın.

Return INTENSITY control to maximum position. Reduce FOCUS 1 con- ol step by step. As the out-of-focus image of specimen starts moving off- reen, bring it back to center by means of the condenser lens adjusting screws. ntinue the process until FOCUS 1 control reaches its lower limit. Only a nall illuminated area should appear on the screen.

Return FOCUS 1 control to about position 9, where a focused image of ecimen would generally be obtained. Repeat steps 3, 4, and 5 until it be- mes possible (a) to swing FOCUS 1 control down to 1 and back up to focus d have the image of specimen grow symmetrically around screen center; d (b) to vary INTENSITY control without obtaining any shadows across the al viewing screen.

Obtain a focused image at good intensity and vary the FOCUS 2 control. e image will tend to spiral about some center which is not the center of final viewing screen. Bring this rotation center into coincidence with screen center by displacing the objective lens by means of its adjusting rews. If, during this adjustment, the illumination tends to disappear, store it by means of the R. H. ALIGNMENT and L. H. ALIGNMENT con- ls. NOTE: If, during the process, the maximum range of these two ntrols is reached, it may be necessary to trim the gun by adjusting its gnment screws.

peat steps 3 to 7 inclusive until a focused image can be obtained on the al viewing screen, its intensity can be varied smoothly, and it will ate about the center of the screen as FOCUS 2 control is moved through focus position.

TENDED-RANGE INTERMEDIATE LENS.

e extended-range lens coil assembly is mounted along the microscope umn in place of the intermediate chamber used in earlier equipments illustrated in Figure 37. The intermediate viewing screen of the ear- r equipments is also done away with. As shown in the schematic dia- m, the assembly consists of a coil, the magnetic field of which is in h of the electron beam. The coil is shunted electrically by a 1500-ohm entiometer, R131, which is mounted behind the control panel of the in- ument and is operated by the same knob as the projector lens control

S14 (MAGNIFICATION control). Physically, this potentiometer R131 is mounted in place of the fixed resistor R100 shown in Figure 62 of the instruction book, IB-39008-2.

For the maximum setting (position 10) of this control the magnification obtained is the same (approx. 20,000 diameters) as in instruments which do not have the new extended-range lens. As the control is turned toward the lower settings, the magnification is correspondingly reduced and can be brought down to some 1000 diameters without requiring the pole-piece spacers to be changed, as was necessary with the earlier instruments.

EXTENDED-RANGE LENS KIT MI-12929

The extended-range lens kit, MI-12929, is supplied for installation on Electron Microscopes of the EMU-Series (other than the EMU-2C) to provide them with the extended magnification range feature, described in an earlier paragraph of this Supplement.

EQUIPMENT SUPPLIED.

The equipment supplied with the kit includes the following material:

Quan.	Description	RCA Reference
1	Coil assembly (electron lens)	740656-501
1	Aperture	8843293-1
1	Gasket (vacuum seal)	613792-24
1	Interconnection cable	454972-501
1	Resistor	449665-4
1	Instructions	This sheet
1	Packing list	

INSTALLATION.

1. Admit air into the microscope column by placing the valve-control handle in the LOADING position.

2. Cut off all electric power to the microscope.

3. With a short, flexible lead, connect one end of the resistor supplied with the kit to the slider contact of this resistor. Connect this same point to one of the wires of the interconnection cable supplied and connect the other end of

of the resistor to the other wire of the cable. Then install the resistor behind the microscope control panel in place of resistor R100 (located as shown in Figure 62 of instruction book IB-39008-2), using the original hardware. Attach the two wires, that formerly connected to R100, to the ends of the new resistor so that the slider terminal of this resistor will be connected to the PROJECTOR contact of switch S7, while the other end of the resistor will go to the arm of the MAGNIFICATION switch S14. The original resistor, R100, may be discarded. The new resistor is shown as R131 on the EMU-2C schematic diagram appended to this supplement.

4. Slide back the cover over the opening to the objective chamber.

5. With the forceps provided with the microscope for this purpose, grip the bellows section and remove it (see Figure 15 of the instruction book IB-39008-2).

6. Remove the intermediate-tube casting and also the intermediate viewing screen. Neither of these two pieces will be used after installation of the extended-range lens assembly.

7. Insert the gasket supplied with the kit into the circular groove in the bottom face of the lens coil assembly.

8. Connect the interconnection cable to the lens coil plug.

9. Using the forceps to hold the lens coil handle, insert the lens coil assembly into the microscope column and place it on top of the projector lens, in the space formerly occupied by the intermediate-tube casting. The gasketed face of the lens assembly is its bottom face.

10. Insert the aperture piece in the recess provided on the top face of the lens coil assembly, the countersunk opening of the aperture piece facing downward.

11. Using the forceps, place the bellows, previously removed, over the lens coil assembly.

ADJUSTMENT.

To adjust the slider contact on the new resistor R131 behind the control panel, proceed as follows:

. Insert a test speciment into the specimen chamber, and operate the microscope to obtain an image on the final viewing screen.

. Set the MAGNIFICATION control to position 1.

. Adjust the resistor (R131) slider contact to obtain a magnification of 1000 diameters.

PARTS LIST

When ordering replacement parts, please give RCA Stock Number. Symbol Number, Description, and Drawing Number will be helpful in further identifying the desired part and should be given when no Stock Number is shown in the following list.

The part which will be supplied against an order for a replacement item may not be an exact duplicate of the original part, however, it will be a satisfactory replacement, differing only in minor mechanical or electrical characteristics. Such differences will in no way impair the operation of the equipment.

Symbol Numbers with suffix letters may not be shown on the schematic and are used for relating the parts to the main item of which they are components.

ELECTRON MICROSCOPE
TYPE NO. EMU-2C
MI-12957-D

MAIN ASSEMBLY - 619622-1

Symbol	Stock No.	Description	Drawing No.
S1A, S1B, S2A, S2B, S10A, S10B, S17A, S17B, S18A, S18B	48337	Switch, interlock, male and female	860597-1, -2
S6	55407	Switch, valve control	443553-1
V12	51164	Thermocouple, gauge	439416-1
X40, X41	48254	Connector, male, 2 contact, condenser and objective coil	878441-1
	54932	Clock	443531-1
	17268	Knob, valve control switch	712336-505

COLUMN ASSEMBLY - 8882266-502

	56112	Aperture, objective pole piece	886416-1
	54934	Aperture, beam condenser	878521-1
	58851	Aperture, extended range lens	8843293-1
	48453	Bellows, internal manifold, condenser to specimen chamber	890333-1
	44052	Bellows, internal manifold, objective coil to extended range coil	859962-2
	47760	Bushing, specimen stage control shaft	878754-1
	47695	Cable, lower condenser coil grounding	891403-502
	47761	Collar, specimen stage control shaft	891401-1
	47696	Cushion, column end pieces	891197-1
	47697	Cushion, column shock mounts	891192-2
	47742	Cushion, column	891199-501
	47745	Gasket, external manifold	613792-59
	47753	Gasket, extended range coil to diffraction unit	613792-24
	47755	Head, internal manifold head, objective coil to extended range coil	878509-1
	47748	Hose, diffusion pump water	891102-1
	48003	Hose, dehydrator to valve mechanism	891102-2
	48016	Knob, stage control	891467-501
	48796	Magnifier, viewing screen	427459-501
	47757	Manifold, external	442054-1
	48798	Manifold, internal, objective coil to extended range coil	427248-501
	48797	Manifold, internal, condenser lens to specimen chamber	890331-501
	44116	Mounting, column shock mounting	834180-7
	47921	Shaft, specimen Stage control flexible shaft	427237-501
	47756	Spring, internal manifold, objective coil to extended range coil	718955-23
	48452	Spring, internal manifold, gun condenser lens to specimen chamber	718955-28

ELECTRON GUN - SELF BIAS - 449745-501

Symbol	Stock No.	Description	Drawing No.
	58635	Cap, filament	892002-1
	58636	Block, filament mounting	
		A1 Block	892001-1
		B1 S.S., #4-40 thd x 1/8"	843365-41
	58171	Bushing, filament mounting block	802332-2
	58637	Terminal, filament lead	8893811-1
	61455	Washer, vellutex, filament terminal	860618-1
	44511	Filament, electron gun	Radiotron FM-2379
	50993	Screw, filament, set screw #4-40 thd x 1/8"	843365-41
	48140	Gasket, electron gun assembly, bottom	613792-61
	48139	Gasket, electron gun assembly, top	613792-60
	48141	Gasket, anode assembly, bottom To Condenser Lens	613792-65

ANODE ASSEMBLY - 740659-501

	58875	Coil, beam alignment	8843298-501
	32054	Connector, alignment coil cable, male, 4 contact	180710-3

UPPER CONTROL PANEL ASSEMBLY - 613736-502

A1, A2, A3, A4	31480	Pilot Lamp, 6-8 volt	61114-22
C15	70641	Capacitor, 1.0 mfd, 600 volts	72086-231
R11	72635	Resistor, 100,000 ohms, 1 watt	727836-86
R12	48184	Resistor, 750 ohms, 10 watts	427230-34
R13	48185	Resistor, 41.6 ohms, 1 watt	891402-6
R22	28090	Resistor, 6000 ohms, 25 watts	427230-22
R23	48192	Resistor, 400 ohms, 20 watts	878434-1
R24	39380	Resistor, 27 ohms, 1 watt	727836-43
R26, R27, R71, R73	48193	Resistor, 800 ohms, 25 watts	427230-31
R57	71988	Resistor, 47,000 ohms, 1 watt	727836-82
R61	48194	Resistor, 4 ohms, 1 watt	891402-2
R66	48209	Resistor, 2000 ohms, 25 watts	427230-32
R72	48771	Resistor, 1 meg, 1 watt	891029-5
S3, S4	48904	Switch, toggle, DPST, panel lights and main power	878368-5
S5	48238	Switch, rotary, condenser, "Off-On"	427246-1
S7	47118	Switch, rotary, diffraction-projection	427247-1
S8	48905	Switch, toggle, high voltage "On-Off"	878368-4
S11	48240	Switch, test rotary	427472-1
S12	48238	Switch, rotary, objective "On-Off"	427246-1
S13	48906	Switch, SPDT, room lights	878368-6
V9, V25	RCA-991	Tube, neon indicator, pressure and overload	RCA-991
X1, X2	48250	Socket, for V9, V25	878367-2
X4, X5, X6, X7	34449	Socket, for A1, A2, A3, A4 pilot lamps	39026-505

LOWER CONTROL PANEL ASSEMBLY - 613737-502

M1	46028	Meter, fore pressure	430501-1
M2, M3	46030	Meter, column pressure and beam	430501-2
M4	46032	Meter, test	430501-3
R19, R21, R64	48208	Rheostat, 10,000 ohms, 50 watts	878370-3
R25	46857	Rheostat, 1000 ohms, 25 watts	415457-23
R63	48207	Resistor, 3300 ohms, 10 watts (part of S9)	878435-13
R70	48210	Resistor, 8000 ohms, 50 watts	878370-1
R74	48211	Resistor, 250 ohms, 10 watts (part of S9)	878435-2
R75	48212	Resistor, 14 ohms, 1 watt (part of S9)	891402-13
R76	48213	Resistor, 16 ohms, 1 watt (part of S9)	891402-14
R77	48214	Resistor, 18 ohms, 1 watt (part of S9)	891402-15
R78	48215	Resistor, 20 ohms, 1 watt (part of S9)	891402-5
R79	48216	Resistor, 23 ohms, 1 watt (part of S9)	891402-16
R80	48217	Resistor, 26 ohms, 1 watt (part of S9)	891402-17

Symbol	Stock No.	Description	Drawing No.
R81	48218	Resistor, 30 ohms, 1 watt (part of S9)	891402-18
R82	48219	Resistor, 36 ohms, 1 watt (part of S9)	891402-19
R83	48185	Resistor, 41.6 ohms,1 watt (part of S9)	891402-6
R84	48221	Resistor, 51 ohms, 1 watt (part of S9)	891402-20
R85	48222	Resistor, 63 ohms, 1 watt (part of S9)	891402-21
R86	48223	Resistor, 79 ohms, 1 watt (part of S9)	891402-22
R87	48224	Resistor, 103 ohms, 1 watt (part of S9)	891402-23
R88	48225	Resistor, 137 ohms, 1 watt (part of S9)	891402-24
R89	48226	Resistor, 198 ohms, 1 watt (part of S9)	891402-25
R90	48227	Resistor, 304 ohms, 1 watt (part of S9)	891402-26
R91	48228	Resistor, 523 ohms, 1 watt (part os S9)	891402-27
R92	48229	Resistor, 1150 ohms, 1 watt (part of S9)	891402-28
R93	48230	Resistor, 4440 ohms, 1 watt (part of S9)	891402-29
R101, R102, R105, R109, R110	2736	Resistor, 180 ohms, 1 watt (part of S14)	90496-141
R103, R106, R111	30497	Resistor, 270 ohms, 1 watt (part of S14)	90496-145
R104, R114	11670	Resistor, 330 ohms, 1 watt (part of S14)	90496-147
R107	31388	Resistor, 390 ohms, 1 watt (part of S14)	90496-149
R108	71916	Resistor, 1000 ohms, 1 watt (part of S14)	90496-159
R127	71914	Resistor, 10,000 ohms, 1 watt	727836-183
R129, R130	59024	Potentiometer, 175 ohms, 25 watts	415457-31
R131	16900	Resistor, adjustable, 1500 ohms, 25 watts	449665-4
S9	46066	Switch, rotary, objective #1	878461-1
S14	48242	Switch, rotary, magnification	427473-1
X68, X71	43377	Socket, 8 contact	844041-505
X69	48253	Socket, 11 contact	891473-1
X70	48259	Socket, 5 contact	878746-3
	17268	Knob, control	717296-502

TOP CHASSIS ASSEMBLY -613728-502

C17, C33, C35, C36, C38, C39, C42	73557	Capacitor, 0.1 mfd, 600 volts	72086-228
C18, C19, C20	70620	Capacitor, 1.0 mfd, 200 volts	72086-111
C21	73553	Capacitor, 0.05 mfd, 400 volts	72086-166
C22	70654	Capacitor, 0.025 mfd, 1000 volts	72086-283
C25	47852	Capacitor, 0.01 mfd, 1200 volts	891363-1
C32	70627	Capacitor, 0.005 mfd, 600 volts	72086-217
C34	70640	Capacitor, 0.5 mfd, 600 volts	72086-230
C37	70620	Capacitor, 1.0 mfd, 200 volts	72086-81
C40	54346	Capacitor, 0.001 mfd, 500 volts	727866-147
C41	39670	Capacitor, 0.006 mfd, 500 volts	727866-165
C43	48813	Capacitor, 0.004 mfd, 1200 volts	891363-4
C45	39630	Capacitor, 120 mmfd	722013-525
J23	48173	Connector, female, 3 contact	891135-1
K2	50792	Relay, overload	430560-501
L8	48815	Coil, oscillator	426612-501
L9	28017	Coil, choke	900526-502
L10	48178	Coil, choke	890305-1
R15, R18	38884	Resistor, 560 ohms, 1 watt	727836-59
R17	48187	Resistor, 200 ohms, 10 watts	878435-12
R28, R58	33554	Resistor, 820,000 ohms, 1 watt	727836-97
R29, R40, R68	48194	Resistor, 4 ohms, 1 watt	891402-2
R30	19783	Resistor, 560 ohms, 1/2 watt	727834-59
R31	48195	Resistor, 2500 ohms, 50 watts	427230-6
R32, R118	48196	Resistor, 500 ohms, 25 watts	427230-3
R33, R60	14583	Resistor, 220,000 ohms, 1/2 watt	727834-90
R34	48186	Resistor, 100 ohms, 10 watts	427230-1
R35	32726	Resistor, 560,000 ohms, 1 watt	727836-95
R36	19660	Resistor, 5000 ohms, 10 watts	878435-4
R37	48771	Resistor, 1 meg, 1 watt	891029-5
R38	69640	Resistor, 10 ohms, 1 watt	727836-38
R39	31215	Resistor, 100 ohms, 1 watt	727836-50
R41	48201	Resistor, 500 ohms, 10 watts	878435-3
R42, R53	33554	Resistor, 820,000 ohms, 2 watts	727838-97
R46	51869	Resistor, 10,000 ohms, 10 watts	878435-19

Symbol	Stock No.	Description	Drawing No.
R47	48204	Resistor, 18,000 ohms, 10 watts	878435-5
R48, R51	30651	Resistor, 270,000 ohms, 1/2 watt	727834-91
R49	30409	Resistor, 27,000 ohms, 1/2 watt	727834-79
R50	18757	Resistor, 18,000 ohms, 1 watt	727836-77
R52	48205	Resistor, 6.5 meg, 2 watts	878432-2
R54	72635	Resistor, 100,000 ohms, 1 watt	727836-86
R55, R67	71914	Resistor, 10,000 ohms, 1 watt	727836-74
R56, R59	38888	Resistor, 8200 ohms, 1 watt	727836-73
R69	48817	Resistor, 35,000 ohms, 10 watts	878435-14
R94	34765	Resistor, 100 ohms, 1/2 watt	82283-50
R95	48232	Resistor, 10,000 ohms, 75 watts	427230-9
R96, R98	38884	Resistor, 560 ohms, 1 watt	727836-59
R97, R99	34765	Resistor, 100 ohms, 1/2 watt	82283-50
R117	71989	Resistor, 22,000 ohms, 1 watt	727836-78
R132, R133, R134, R135	59023	Resistor, 1 ohm, 1 watt	891402-1
T4	48245	Transformer	901389-501
T7	46033	Transformer	878736-1
T8	64306	Transformer	878739-1
V26	RCA-991	Tube, neon	RCA-991
X3	48250	Socket, tube	878367-2
X27, X29, X34, X35, X36, X37	18007	Socket, tube	844041-503
X28, X31, X32	19458	Socket, tube	844933-3
X30, X33, X38	19395	Socket, tube	844933-2
X39	48253	Socket	891473-1
X53	48257	Socket	891495-3

LOWER CHASSIS - 302945-503

A5	48818	Lamp, 6 watts, 118 volts	849546-9
C1, C2	43993	Capacitor, 1 mfd, 1500 volts	878373-1
C3	48158	Capacitor, 1 mfd, 2000 volts	878374-1
C4, C5, C6, C7, C8, C9, C10, C11	48159	Capacitor, 125 mfd, 350 volts	86060-6
C12	54346	Capacitor, 0.001 mfd, 500 volts	727866-147
C13	73557	Capacitor, 0.10 mfd, 600 volts	72086-228
C14	70641	Capacitor, 1.0 mfd, 600 volts	72086-231
C16	70620	Capacitor, 1.0 mfd, 200 volts	72086-111
F1, F2	48819	Fuse, 15 amps	99043-4
F7	10907	Fuse, 3 amps	55544-4
K1	53915	Relay, vacuum interlock	445262-1
L1, L2	46045	Coil, choke	878371-1
L3	46044	Coil, choke	878375-2
L4, L5	46340	Coil, choke	878375-1
R1	48820	Resistor, 0.8 ohm, 10 watts	878435-15
R2	48180	Resistor, 50,000 ohms, 1 watt	891402-8
R3, R62	48181	Resistor, 80,000 ohms, 1 watt	896199-2
R4	14583	Resistor, 220,000 ohms, 1/2 watt	727834-90
R5	52012	Resistor, 680,000 ohms, 1 watt	727836-96
R6, R7	19783	Resistor, 560 ohms, 1/2 watt	727834-59
R8	48182	Resistor, 75,000 ohms, 1 watt	896199-1
R9	34767	Resistor, 2200 ohms, 1/2 watt	727834-66
R10	48183	Resistor, 660,000 ohms, 4 watts	878437-1
R14	52463	Resistor, adjustable, 15 ohms, 10 watts	427491-22
R16	71993	Resistor, 1 meg, 1 watt	727836-98
R20	48189	Resistor, 50,000 ohms, 50 watts	427230-35
R112	43609	Rheostat, 10 ohms, 100 watts	849811-1
R113	48821	Resistor, 5 ohms, 50 watts	427491-1
R115, R116	45884	Resistor, 47 ohms, 1 watt	727836-46
R119, R120, R121, R122, R123, R124, R125, R126	72635	Resistor, 100,000 ohms, 1 watt	727836-86
T1	46047	Transformer	891390-1
T2	48244	Transformer	878376-1
T3	46036	Transformer	878377-1
T5	48246	Transformer	878372-1
T6	17692	Transformer	900168-502

Symbol	Stock No.	Description	Drawing No.
T9	48247	Transformer	878735 1
X8, X9, X10	23540	Socket, for A5, F1, and F2	99014-1
X12, X13, X14, X18, X19, X20, X21, X22, X23, X25	18007	Socket, tube	844041-503
X16, X17	19458	Socket, tube	844933-3
X24	48251	Socket, receptacle for W6	878746-1
X26	48252	Socket, receptacle for W4	878746-2
X57, X58, X59, X60, X61, X62, X63, X64	45368	Socket, capacitor, for C4, C5, C6, C7, C8, C9, C10, C11	181516-2
X74	45851	Socket, fuse, for F7	844027-2
		HIGH VOLTAGE UNIT - 302951-501	
C24	47933	Capacitor, 0.006 mfd, 600 volts	891363-3
C26, C27, C28, C30	553405	Capacitor, 0.0005 mfd	504400-501
C29	47935	Capacitor, 0.025 mfd, 50,000 volts	718572-1
C31	54535	Capacitor, 1.0 mfd, 600 volts	981040-4
C44	57490	Capacitor, 0.000025 mfd	8899337-1
L13	47938	Coil, tank	427255-501
L15	48468	Coil, ripple trap	427456-501
R65	47940	Resistor, 1000 meg	869085-1
T12	47941	Coil, filament transformer	427256-501
T13	47938	Coil, filament transformer,(part of L13)	427255-501
X48, X49, X50	47942	Socket, tube	878546-1
X51	48256	Socket, tube	891136-1
		HIGH VOLTAGE BUSHING - 613583-503	
C46	53017	Capacitor, 0.0047 mfd	727876-163
R43	48202	Resistor, 200,000 ohms, 6 watts	859882-1
R44, R45	48203	Resistor, 47 ohms, 1/2 watt	850981-46
R128	2970	Resistor, 0.51 meg, 1 watt	727836-224
	47351	Coil, outer coil assembly (part of T10)	718956-501
	48035	Coil, inner coil assembly (part of T10)	430518-501
X73	48261	Connector, male, 3 contact, for W12	891494-1
		SOLENOID VALVE ASSEMBLY	
	55703	Coil, solenoid coil assembly, A, B, C, and D valves	8887198-501
	55678	Gasket, plunger, 11/16" diam, 3/16" hole, B and D valves	8887199-1
	55679	Gasket, plunger tube, 1-1/16" diam, 27/32" hole	8887199-2
	48715	Gasket, valve assembly to valve block, A, B and D valves	613792-76
	48486	Gasket, valve assembly to column gasket, C valve	613792-69
	53633	Gasket, vacuum, line fitting	613792-88
	55680	Gasket, valve, A, B, and D valves, rubber 7/8" diam, 3/8" hole	8887199-4
	55681	Gasket, valve, C valve, 2-5/16" diam, 3/8" hole	8887199-3
	55744	Spring, A valve plunger	8888434-2
	58172	Spring, B valve plunger	8899342-1
	55973	Spring, C valve plunger	8888434-1
	55745	Spring, D valve plunger	8888433-1

POWER SUPPLY FOR SOLENOID VALVES - 8899319-502

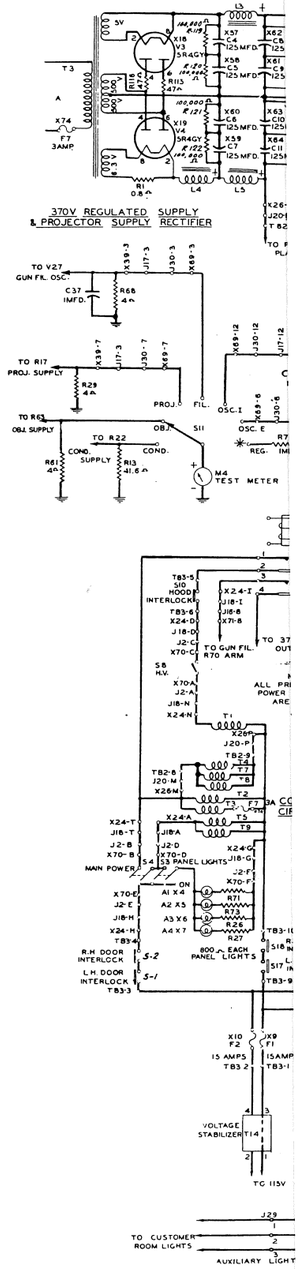
Symbol	Stock No.	Description	Drawing No.
C601, C602	55406	Capacitor, 50 mfd, 165 volts	8882234-1
C603	48159	Capacitor, 125 mfd, 350 volts	86060-6
C604, C605	70620	Capacitor, 1.0 mfd, 400 volts	72086-141
F601, F602	10907	Fuse, 3 amps	55544-4
J601	55410	Connector, male, 2 contact	8882232-1
J602	55409	Connector, male, 8 contact	8882233-1
R601	46328	Resistor, 25 ohms, 50 watts	427491-29
S601	51342	Switch, toggle, power, SPST	413702-23
T601	58181	Transformer, filament	949094-1
X601	9917	Socket, tube	429151-1
X602, X603	45851	Holder, fuse	844027-2
X604	31319	Socket, capacitor, for C603	87156-1
W601	58182	Cable, valve cable and connector assembly	443563-502
		SPECIMEN CHAMBER - 718946-501	
	48406	Cam Assembly, door knob shaft and cam	891186-501
	48483	Cap, specimen holder cap	892010-1
	48378	Gasket, specimen chamber, bottom	613792-71
	48384	Gasket, specimen chamber door	613792-86
	48408	Gasket, door knob shaft	613792-85
	48374	Gear, micrometer	891164-1
	48405	Knob, specimen chamber door	891176-1
	48387	Lifter Assembly, specimen	878580-501
	47985	Packing, door knob shaft and micrometer screw	878391-1
	47628	Screen, specimen mounting screen	891152-1
	48377	Screw, micrometer	891166-1
	48376	Shaft, worm gear	891177-1
	48404	Specimen holder, stereo	891194-501
	48390	Specimen holder, standard	891193-501
	48407	Spring, door knob shaft	718955-18
	48805	Spring, knob limit pin	718955-10
	48379	Spring, micrometer gear, L.H.	890320-1
	48380	Spring, micrometer gear, R.H.	890320-2
	48010	Spring, micrometer screw	718955-13
	48385	Spring, stage clamp	890334-1
	48381	Spring, stage anvil, 2 anvils	878726-501
	48382	Spring, stage anvil, 2 anvils, 1 slotted	878726-502
	48383	Spring, stage anvil, 1 anvil	878726-503
	48375	Worm, micrometer gear	891164-2
		DIFFRACTION UNIT - 613750-502	
	48255	Connector, male	878440-1
	48807	Gasket, diffraction unit, bottom	613792-66
	47127	Gasket, window	613792-41
	47129	Window, diffraction unit	870447-1
		DIFFRACTION STAGE ASSEMBLY - 718680-501	
	47149	Aperture, reflection	870440-2
	47116	Ball, axial adjusting rod	76757-18
	48032	Bushing, packing	878536-1
	48483	Cap, specimen holder	892010-1
	56163	Gasket, pushrod, felt	897600-1
	48027	Gasket, stage assembly	613792-73
	48031	Handwheel, stage assembly, less handles	878719-1
	47115	Handle only, for handwheel	878533-1
	46999	Packing, pushrod	878391-2

Symbol	Stock No.	Description	Drawing No.
	47105	Pin, swivel, tilting pushrod	878535-1
	47102	Pushrod assembly, tilting	870430-501
	47103	Pushrod assembly, rotary, and axial adjustment	870430-502
	48028	Ring, stage gasket thrust	870411-3
	47628	Screen, specimen	891152-1
	47117	Shaft, axial adjusting	870432-3
	47106	Specimen holder, reflection	878527-1
	47107	Specimen holder, transmission	870440-1
	46998	Spring, conical, tilting pushrod	878534-1
	46997	Spring, pushrod packing	718955-9
	47111	Thumb wheel, specimen rotation	870429-1
	47112	Thumb wheel, transverse adjustment	878741-1
	47113	Thumb wheel, angular adjustment	878740-1
		VIEWING CHAMBER ASSEMBLY - 613725-502	
V13	51165	Ionization gauge	439409-501
	48021	Bracket, rack gear	891123-1
	48013	Cable release, screen movement	878492-1
	47735	Gasket, viewing chamber, bottom	613792-57
	53631	Gasket, ionization gauge	613792-87
	48009	Gasket, pinion sleeve	613792-84
	48012	Gasket, window	613792-79
	48007	Gear assembly, screen movement	878477-501
	48014	Magnet, ionization gauge	427438-1
	47985	Packing, viewing screen shaft	878391-1
	48008	Rack, screen movement rack gear	878479-1
	48656	Screen, ionization gauge	859388-3
	48005	Screen, viewing screen assembly	427228-501
	48015	Spring, screen counter balance	891471-1
	48010	Spring, pinion shaft packing	718955-13
	48006	Window, viewing	878320-2
	51579	Fluorescent coating, 25 gm bottle	
		PHOTO CHAMBER - 613717-501	
	47986	Bearing, pinion shaft	855201-4
	47995	Gasket, cassette door	613792-80
	47981	Gasket, stuffing box	613792-67
	47989	Handle, photo chamber door	
		A1 handle	899424-501
		B1 taper pin	55127-21
	47991	Hinge, photo chamber door	
		A1 hinge	878319-1
		B1 pin	878335-2
	47987	Gear, cassette pinion	878399-1
	17268	Knob, cassette control	712336-501
	47990	Lock bolt, photo chamber door	878315-1
	47985	Packing, control knob shaft	878391-1
	47994	Pin, cassette detent	878568-1
	47993	Rack, cassette carriage	878381-1
	47992	Screw, stop screw, photo chamber door	878318-1
	47984	Shaft, knob, cassette control	878401-1
	48808	Shaft, pinion gear, cassette control	878402-1
	47983	Spring, packing, control knob shaft	718955-12
	47982	Spring, cassette detent pin	718955-26
MI-12977-A		Cassette and cover	427219-501
		VACUUM PUMP	
	48843	Belt, motor drive	Part of 718951-1
	48844	Motor, 50 cycles, 115-230 volts	Part of 718951-2
	48842	Motor, 60 cycles, 115-230 volts	Part of 718951-1
	48845	Oil, vacuum pump	890324-1
	48841	Pump, vacuum pump only	Part of 718951-1
	58307	Pulley, motor drive	Part of 718951-1

BATTERY BOX - 8882269

Symbol	Stock No.	Description	Drawing No.
B1, B2, B3, B4, B5, B6, B7, B8, B10	47213	Battery, 45 volts	891434-1
B9, B11	48411	Battery, 22-1/2 volts	891435-1
F4, F5, F6	3748	Fuse, 1/2 amp	55544-11
J1, J3, J4, J5, J6, J7, J8, J9, J10	47943	Connector, battery cable terminal	878438-1
X44, X45, X46	45851	Fuse holder, for F4, F5, F6	844027-2
X47	18007	Socket, for W2	844041-503
		CABLES AND CONNECTORS - 8882269-502	
W1	48822	Cable, control panel to projection, objective, and condenser coils	427476-501
J11, J12	48168	Connector, female, 2 contact, for W1	878362-1
J13	48836	Connector, female, 3 contact, for W1	878364-1
J14	35383	Connector, male, 8 contact, for W1	413691-8
W2	48823	Cable, top chassis to battery box	427257-501
J24	48838	Connector, male, 8 contact, for W2	890396-1
W3	48824	Cable, control panel to top chassis	427477-501
J17, J30	19976	Connector, female, 12 contact, for W3	891472-1
W4	48825	Cable, top chassis to bottom chassis	427478-501
J20	48170	Connector, female, 14 contact, for W4	878745-2
W5	58642	Cable, column to bottom chassis	443574-501
J19	35383	Connector, male, 8 contact, for W5	413691-8
W6	48827	Cable, control panel to bottom chassis	427480-501
J2	48167	Connector, female, 6 contact, for W6	878745-3
J16	35383	Connector, male, 8 contact, for W6	413691-8
J18	48837	Connector, female, 22 contact, for W6	878745-1
W7	55033	Cable, thermocouple to bottom chassis	427481-502
J15	35354	Connector, female, 8 contact, for W7	413691-9
J25	35383	Connector, male, 8 contact, for W7	413691-8
W8	48829	Cable, bottom chassis to diffusion pump	427482-501
J26	48174	Connector, female, 3 contact, for W8	890317-1
W9	48830	Cable, customer room lights	427497-501
J29	48839	Connector, female, 4 contact, for W9	891475-1
W10	48831	Cable, high voltage unit to top chassis	427484-501
W11	48832	Cable, high voltage unit to top chassis	427485-501
J22	48172	Connector, male, single contact, for W11	878750-1
W12	48833	Cable, top chassis to high voltage bushing	427486-501
J21	53162	Connector, male, 3 contact, for W12	891495-2
J27	48175	Connector, female, 3 contact, for W12	891495-1
W13	48834	Cable, interlock	427489-501
W14	48835	Cable, interlock	427488-501
W18	58891	Cable, top chassis to W19	454966-501
J36	28455	Connector, female, 6 contact, for W18	8845144-2
W19	58893	Cable, control panel to alignment and extended range coils and W18	740662-501
J31	35340	Connector, female, 4 contact, for W19	8845144-1
J33	48836	Connector, female, 3 contact, for W19	878364-1
J35	28454	Connector, male, 6 contact, for W19	181494-2
J37	58977	Connector, male, 8 contact, for W19	430155-1
W20	58892	Cable, control panel to W19	454967-501
J38	50741	Connector, female, 8 contact	430154-1
		MISCELLANEOUS	
	47925	Box, utility	891425-1
	51311	Grease, stop cock	897640-1
	48030	Grease, lubrice	891458-1
	47924	Lifter, pole piece	718950-501
	48387	Lifter, specimen holder	878580-501
	54857	Fluid, diffusion pump (200 C.C. bottle)	8858084-2
	47790	Tongs, internal manifold	427266-501
	46698	Wax, apeizon	890321-1
	46699	Allen wrench, #4 screw	828505-14

Symbol	Stock No.	Description	Drawing No.
	19996	Allen wrench, #6 screw	828505-13
	14991	Allen wrench, #8 screw	828505-12
	26581	Allen wrench, #10 screw	828505-1
	22112	Allen wrench, 1/4" screw	828505-2
	22113	Allen wrench, 5/16" screw	828505-3
	22111	Allen wrench, 3/8" screw	828505-4
	62967	Allen wrench, 5/16" cap screw	828505-5
	64179	Allen wrench, 3/8" cap screw	828505-7
	48389	Wrench, cassette control nut	891409-1
	47926	Wrench, spanner	718950-6
	53766	Dehydrator, less drierite crystals	427422-502
		VACUUM TUBING ASSEMBLY - 443558-501, 502	
	53633	Gasket, vacuum line fitting	613792-88
	58644	Tubing, 22-1/2" long, less fittings, valve block to diffusion pump and column	426698-5



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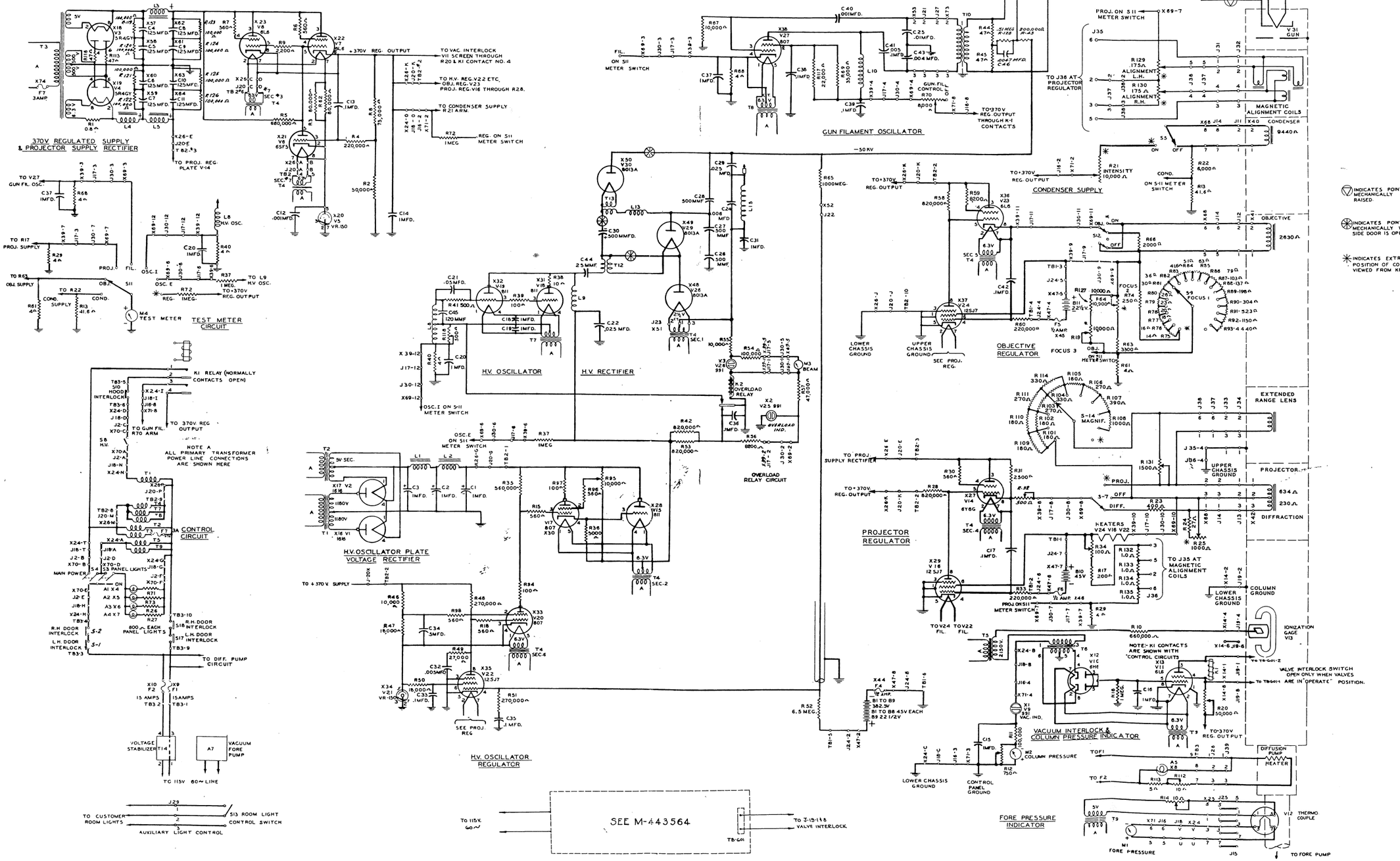

Electron Microscope, Type EMU-2C, Schematic Diagram (W-309860)

ADDENDA TO IB-39008-2

INSTRUCTIONS FOR "EMU" ELECTRON MICROSCOPE

TO INCLUDE

MI-12932 COMPENSATED POLE PIECE

DESCRIPTION

The MI-12932 compensated pole piece has been designed for installation in the Type EMU Electron Microscopes for the purpose of increasing the resolving power of the objective lens by correcting astigmatic aberration caused by asymmetries in the field of the objective lens. These pole pieces are corrected, during manufacture, to within a few microns of complete compensation. Complete compensation can be achieved by the process described below under the title *"Compensation Procedure"*.

Asymmetries of the magnitude encountered in the uncorrected objective may be considered to be caused by the superposition of a cylindrical magnetic lens on an axially symmetrical magnetic lens. The practical method of correction involves, therefore, the production of an additional superimposed cylindrical field which is of the proper strength, and at right angles to the existing cylindrical component.

This is accomplished by means of a device known as a compensated pole piece which is shown in the accompanying illustration.

The adjustable compensating feature consists of eight soft-iron set screws - five-sixteenths inch long, size number one, having 72 threads to the inch - threaded into the wall of the brass pole piece spacer, but inclined to the axis of the lens, and reaching into the plane of the pole piece gap. The location of the compensating setscrews is shown in the accompanying illustration. The iron compensation setscrews are indicated as screws "1" through "8", and the brass setscrews which support the aperture carriage in position are designated "A" through "D".

DISTORTION PHENOMENA*

In the highly magnified images of carbon black particles produced by an objective lens which is astigmatic there is an apparent reversal of the Fresnel fringes about the edges of the holes as the power of the objective is varied through the focal value. It will be observed that the Fresnel fringing is not the same all along the edges of the holes but that contour asymmetry appears.

At best focus the contours in one direction are those obtained when the power of the objective is less than the focal value, while the contours in the direction perpendicular to the first direction are those obtained when the power of the objective is greater than the focal value.

Thus, a focal sequence or series of photographs of: focused, underfocused, and overfocused images can be made the basis for a systematic correction procedure such as the method outlined below.

*For complete information refer to the report by James Hillier and E.G. Ramberg in the Journal of Applied Physics, Vol. 18, No. 1, 48-71, January 1947, titled: *The Magnetic Electron Microscope Objective: Contour Phenomena and the Attainment of High Resolving Power.*

COMPENSATION PROCEDURE

Before starting compensation the aperture carriage - but no aperture - should be in position in the spacer and centered as well as possible visually. This may be done by observing the clearance between the carriage and the spacer wall. The compensating screws are then inserted in the withdrawn position.

To adjust the setscrews in the pole piece to correct the astigmatism in the objective perform the following operations:

1. Make a focal sequence - a series of photographs, of a suitable specimen, such as carbon black, at different focal values - with the setscrews adjusted so that they are approximately equidistant from the axis of the lens, and withdrawn as far as possible from the axis. Note the orientation and magnitude of the asymmetry on the appropriate exposure.

2. Move any two diametrically opposite setscrews as far as possible toward the axis and make a second sequence of photos under focal conditions identical to those in step "1" above. This operation introduces an extreme degree of asymmetry, and permits a correlation to be made

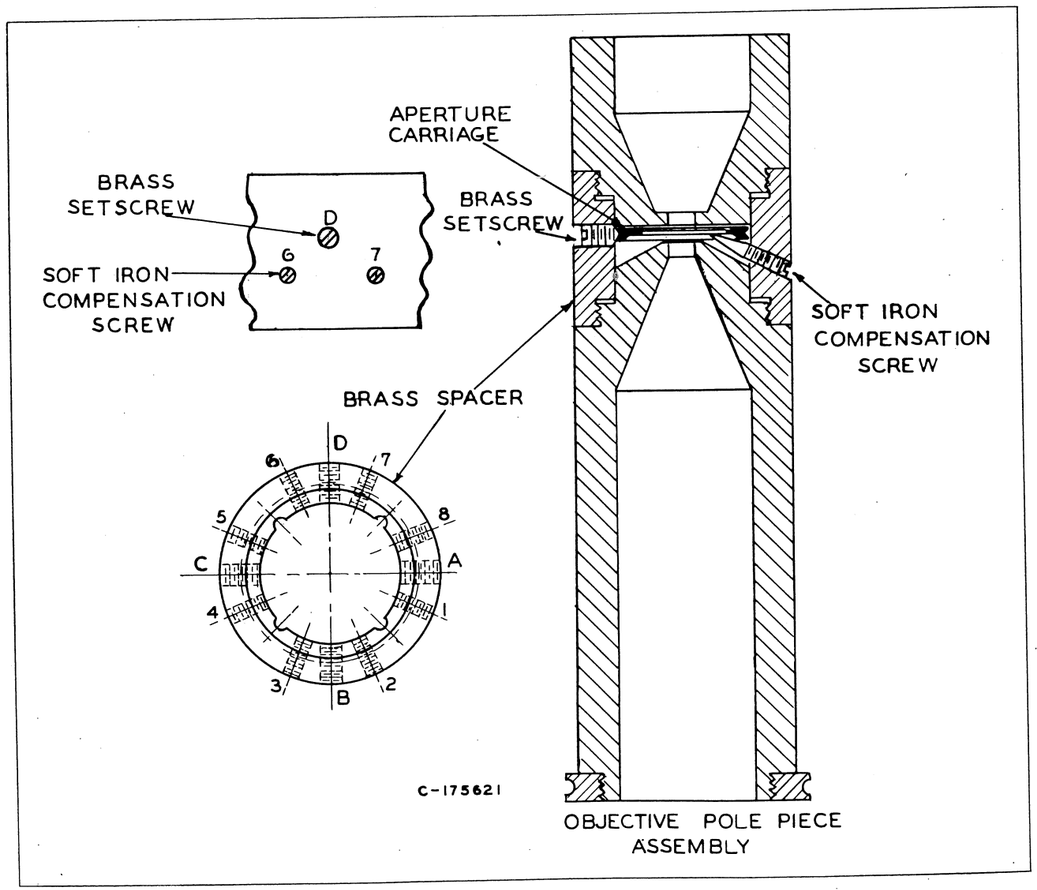

Figure 1 - MI-12932, Compensated Pole Piece Assembly

between the direction of the asymmetry in the image and the direction of the setscrew adjustment, or the position in azimuth of the setscrews causing the asymmetry.

3. Compare the focal sequence obtained in steps "1" and "2" to determine which pair of setscrews must be moved toward the axis in order to correct for the asymmetry shown in the photos obtained in step 1. Make the compensation adjustment in the direction perpendicular to the center line through the pair of setscrews which would - if appropriately moved - increase the asymmetry observed in the first focal sequence - obtained in step 1. Starting with the setscrews equisdistant from the pole piece axis, turn the two screws five turns - clockwise - so that they will move inward toward the pole piece axis, and make a third focal sequence. Determine the direction and degree of asymmetry remaining from a study of the proper image.

4. If the asymmetry is found to be decreased but has not changed direction, turn the same two setscrews two more turns in the same direction, and make a fourth focal sequence.

The maximum correction attainable by moving any one pair of setscrews towards the pole piece axis is reached when the direction of the asymmetry in the image is rotated through an angle of 45 degrees.

5. With the setscrews which were adjusted in steps 3 and 4, above, set in the position where the direction of the asymmetry has been rotated by an angle of 30 to 45 degrees from its original direction; compare the last or fourth focal sequence of photos with the second group of photos - obtained in step 2 - to determine the new direction of correction.

6. With the setscrews in the newly selected direction advanced slightly - about four turns - toward the axis, make another focal sequence. Study the photographs and continue increasing the correction in this new direction, until the direction of asymmetry again changes direction, 30 to 40 degrees.

7. Continue the systematic compensation of the asymmetries, by this method until no asymmetry can be detected in the photographic images.

With proper handling a compensation will be maintained through many months of operation. It is inadvisable and usually unnecessary to clean the spacers or compensating screws between periods of adjustment. If small amounts of lint enter the spacer they can be blown out gently.

Records should be kept of each compensation of the pole piece to simplify subsequent adjustments. A record sheet such as figure 2 is useful as a guide and record of the adjustment.

- WARNING -

Abrasive cleaning of the pole piece faces or holes frequently results in the destruction of compensation.

MICROSCOPE ADJUSTMENT

In describing the correction of the objective lens no mention has been made of the adjustment of the other components of the electron microscope. It is obvious that all the images used in the course of the correcting procedure must be obtained under identical electron-optical conditions. The compensation obtained by the technique set forth above is accurate only at a certain adjustment of the instrument. As would be expected, the method described corrects not only the asymmetries inherent in the lens, but also those introduced by stray fields from the other components of the instrument. The various phenomena encountered and the adjustments which must be carried out if the procedure is to give consistent results are listed below:

1. *Specimen.* – A suitable specimen must be used. Spherical carbon-black particles mounted without a supporting membrane have been found to be most satisfactory. Smoke from burning camphor is suitable. Crystalline materials should be avoided because of the artificial

COMPENSATION RECORD

Pole Piece 3 Magnification 20,000

Reference Position Screw # 1 front

		COMPENSATION SCREW SETTINGS (ALL TURNS TOTAL)									
Adjustment	Plate #	1	2	3	4	5	6	7	8	Assymetry (Low Current)	Remarks
1	288	all	screws	retracted						30°	Pole piece cleaned before compensation
2	289				all in				all in	0°	
3	290			3 turns in	all out			3 turns in	all out	15°	
4	304			4½				4½ in		0°	
5	305		3	4½			3	4½		90°	
6	306		2	4½			2	4½			astigmatism less than ⅓ of fine division on objective

Date Jan 14, 1950

Operator John Doe

Figure 2 - Suggested Pole Piece Compensation Record Form

asymmetries sometimes introduced by different interactions of the electron beam with different faces of the crystals.

2. *Illumination.* - The angular aperture of the illumination should be kept as small as possible in order to obtain the sharpest possible definition in the contour fringes. That is the condenser lens current should be as far above the crossover point as is permitted by the visibility of the image.

3. *Lens Position.* - The objective pole-piece assembly must be replaced in exactly the same position in the objective lens coil structure each time it is put back after making an adjustment. This concerns only the angular orientation since the axial position is usually fixed by the structure of the lens. The numbers on the spacer may be used as a reference for positioning the pole piece in the objective lens.

4. *Specimen Position.* - It is obvious that an empirical method of compensating for lens field asymmetries arising as a result of imperfections in the magnetic properties of the material will be precise for only one condition of magnetization. This means that the specimen position must be accurately reproduced both during the compensation of the lens and during subsequent high resolution work.

5. *Magnification.* - This last condition insures that the objective magnification will be constant during its compensation and use. Because of the stray fields produced by the projection lens, and the dependence of the alignment on the power of the projection lens, it will be found necessary to keep its magnification constant, preferably at the magnification at which the pole piece is to be utilized. If no specific magnification is contemplated for the objective lens, the compensation adjustments should be made, on the pole piece, at the highest magnification.

OBJECTIVE APERTURE ADJUSTMENT

If it is desired to use an aperture to enhance the contrast of an image the upper portion of the pole piece should be unscrewed and the aperture and the hold down spring installed on the aperture carriage and the top of the pole piece screwed on to the spacer.

In general the opening of the aperture will not coincide with the center of rotation of the objective lens. In order to facilitate observations, centering of the aperture should be observed at the lowest magnification of the projector lens. A method of trial and error - in adjusting the brass setscrews - can be employed to align the aperture carriage so as to make the aperture center coincide with the center of rotation of the objective lens.

Replacement Parts

The following parts list is included to provide identification when ordering replacement parts. Order from *RCA Replacement Parts Department, Camden, New Jersey,* giving the *Stock Number* and *Description* of the parts wanted. Replacement parts supplied may be slightly different in form or size from the original parts but will be completely interchangeable with them.

LIST OF PARTS

Stock No.	*Description*	*Drawing No.*
93502	Screw, aperture spacer adj. screw, brass	8849590-2
93501	Screw, compensation, iron	8849590-1
93499	Aperture, objective aperture	886416-4
93500	Spacer, aperture holder	8849589-1

RADIO CORPORATION OF AMERICA
ENGINEERING PRODUCTS DEPARTMENT CAMDEN, N. J.

PRINTED IN U.S.A.
511

ELECTRON MICROSCOPE

EMU SERIES

INSTRUCTIONS

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Camden, New Jersey, U. S. A.

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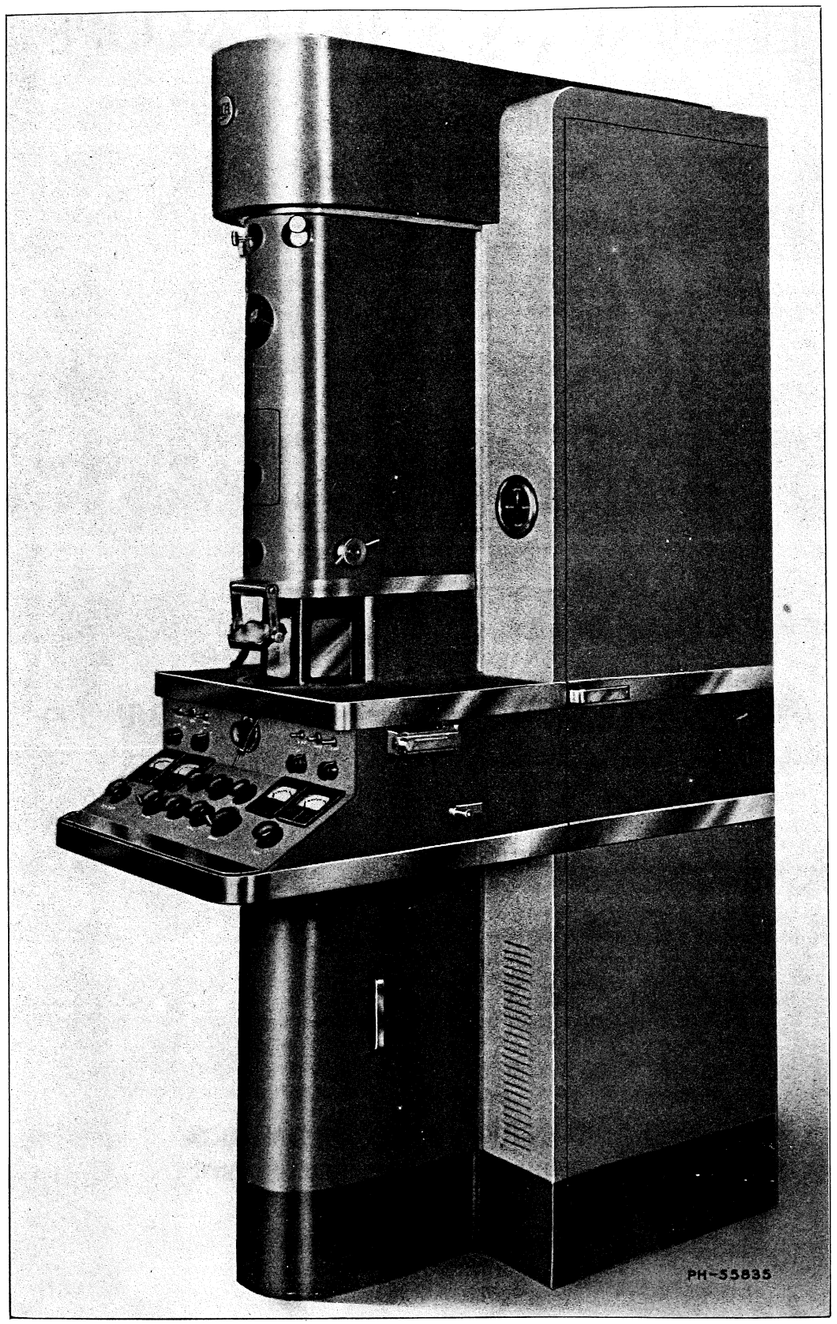

Figure 1—Electron Microscope, Type EMU, Oblique Front View

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TECHNICAL SUMMARY

EQUIPMENT:

The Electron Microscope Types EMU-1, EMU-2, EMU-2A, complete with associated equipment are identified as follows:

Designation	Power Required	Items		Quan.
MI-12951	115 volts, 60 cycles	Electron Microscope EMU-1	MI-12957	1
		Vacuum Pump (Hypervac 20)	MI-12956-B	1
		Voltage Stabilizer	MI-12959	1
		Accessory Kit	MI-12980-B	1
		Instruction Books	IB-39008-2	2
MI-12951-A	230 volts, 50 cycles	Electron Microscope EMU-1	MI-12957	1
		Vacuum Pump (Hypervac 20)	MI-12956-C	1
		Voltage Stabilizer	MI-12959-A	1
		Accessory Kit	MI-12980-B	1
		Instruction Books	IB-39008-2	2
MI-12951-B	115 volts, 50 cycles	Electron Microscope EMU-1	MI-12957	1
		Vacuum Pump (Hypervac 20)	MI-12956-C	1
		Voltage Stabilizer	MI-12959-B	1
		Accessory Kit	MI-12980-B	1
		Instruction Books	IB-39008-2	2
MI-12951-C	115 volts, 60 cycles	Electron Microscope EMU-2	MI-12957-A	1
		Vacuum Pump (Hypervac 20)	MI-12956-B	1
		Voltage Stabilizer	MI-12959	1
		Accessory Kit	MI-12980-C	1
		Instruction Books	IB-39008-2	2
MI-12951-D	230 volts, 50 cycles	Electron Microscope EMU-2	MI-12957-A	1
		Vacuum Pump (Hypervac 20)	MI-12956-C	1
		Voltage Stabilizer	MI-12959-A	1
		Accessory Kit	MI-12980-C	1
		Instruction Books	IB-39008-2	2
MI-12951-E	115 volts, 50 cycles	Electron Microscope EMU-2	MI-12957-A	1
		Vacuum Pump (Hypervac 20)	MI-12956-C	1
		Voltage Stabilizer	MI-12959-B	1
		Accessory Kit	MI-12980-C	1
		Instruction Books	IB-39008-2	2
MI-12951-F	115 volts, 60 cycles	Electron Microscope EMU-2A	MI-12957-B	1
		Vacuum Pump (Hypervac 20)	MI-12956-H	1
		Voltage Stabilizer	MI-12959	1
		Accessory Kit	MI-12980-C	1
		Instruction Books	IB-39008-2	2
MI-12951-G	230 volts, 50 cycles	Electron Microscope EMU-2A	MI-12957-B	1
		Vacuum Pump (Hypervac 20)	MI-12956-K	1
		Voltage Stabilizer	MI-12959-A	1
		Accessory Kit	MI-12980-C	1
		Instruction Books	IB-39008-2	2
MI-12951-H	115 volts, 50 cycles	Electron Microscope EMU-2A	MI-12957-B	1
		Vacuum Pump (Hypervac 20)	MI-12956-K	1
		Voltage Stabilizer	MI-12959-B	1
		Accessory Kit	MI-12980-C	1
		Instruction Books	IB-39008-2	2

ELECTRICAL CHARACTERISTICS:

Electronic Magnification (40 steps, 4 ranges) ..... 100 to 20,000 diameters
Resolution ..... Better than 100 Angstrom Units

ANODE POTENTIAL:

With respect to cathode ..... +50 kv.
With respect to instrument ground ..... zero

POWER DATA:

Power Consumption (Maximum) ..... 1,500 watts
Maximum Allowable Line Voltage Variations ..... 2.5 volts in 30 sec. minimum time

TUBE COMPLEMENT:

Item	Type	Quan.	Symbol Number on Schematic Diagram	Class of Tube
1	VR-150	2	V-5, V-21	Receiving
2	6L6	4	V-7, V-8, V-11, V-23	Receiving
3	12SJ7	3	V-16, V-22, V-24	Receiving
4	6Y6G	1	V-14	Receiving
5	6H6	1	V-10	Receiving
6	6SF5	1	V-6	Receiving
7	807	3	V-17, V-20, V-27	Power
8	5R4GY	2	V-3, V-4	Power
9	811	3	V-15, V-18, V-19	Power
10	8013A	3	V-28, V-29, V-30	Power
11	1616	2	V-1, V-2	Power
12**		1	Ionization Gauge (V-13)	Special
13**	991	3	Indicators V-9, V-25, V-26	Neon
14*		1	Thermocouple Gauge (V-12)	Special

* Item 14 (V-12) must be ordered as thermocouple gauge for Electron Microscope Type EMU-1.

** Items 12 and 13 should be ordered by type number or stock number from the Radio Corporation of America, Camden, New Jersey. Ionization Gauge (V-13) stock number is 51165.

Items 1 through 11 are standard tubes ordered through any tube dealer.

MECHANICAL SPECIFICATIONS:

Evacuation (maximum permissible operating pressure) ..... 0.5 micron
Water Flow Requirement ..... 3 cubic centimeters per second

PHOTOGRAPHIC FACILITIES:

Plate Size ..... 2 inches x 10 inches
Exposures per Plate 5

Overall Dimensions	Microscope	Mechanical Pump
Height	75 inches	17½ inches
Width	24 inches	13½ inches
Depth	42 inches	
Length	25 inches	

Total Weight (net) ..... 875 pounds.

INTRODUCTION

GENERAL PURPOSE AND FUNCTIONS OF RCA TYPE EMU ELECTRON MICROSCOPE

The RCA Type EMU Electron Microscope, like the conventional light microscope, is intended to furnish enlarged images of minute objects or specimens. Through the use of an electron beam instead of light waves for illuminating the specimen, the Electron Microscope allows magnifications to be obtained which are considerably greater than those afforded by even the most perfect types of light microscopes. Magnifications as high as 25,000 diameters may thus be reached with the Electron Microscope. Moreover, as will be explained in this Instruction Book, magnification may be adjusted readily to suit particular conditions.

Provision is made, in the design of the type EMU Electron Microscope, for observing the magnified image visually on a fluorescent screen, as well as for recording this image on a photographic plate. A series of such photographs may be made successively without recharging the camera. As an additional feature, magnified stereoscopic micrographs can be taken, which give three-dimensional views of the specimen.

The field of application of the type EMU Electron Microscope is further extended through the inclusion, in the design of the instrument, of the necessary attachments and controls to obtain diffraction patterns by either reflection or transmission methods.

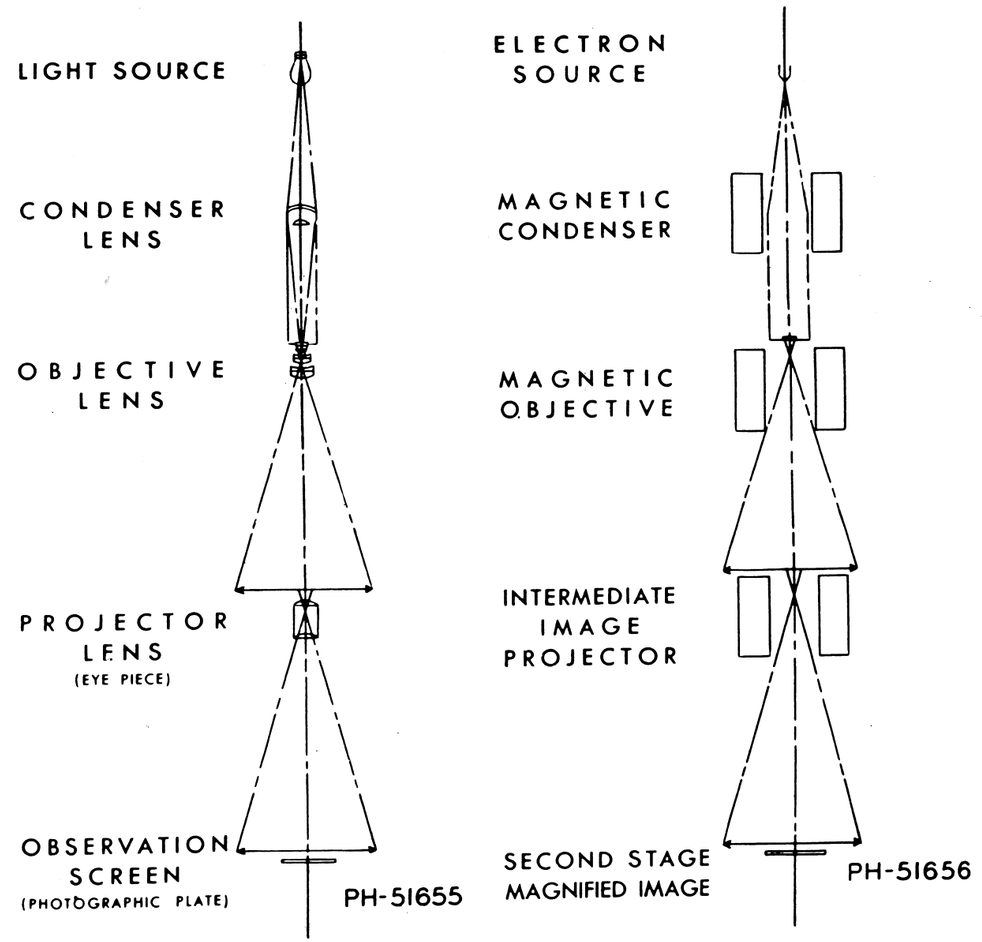


Figure 2—Analogy of Light and Electron Microscopes

PHYSICAL CONSIDERATIONS

The basic principles of the Electron Microscope are in many respects analogous to those of the conventional light microscope. This similarity is illustrated in the drawing of Figure 2 which shows the essential elements of the light microscope at the left and of the electron microscope at the right.

Essentially, the light microscope consists of a light source, a condenser lens which controls the light on the specimen, a specimen stage which in the better grade of instrument incorporates means of moving the specimen in any direction in the plane of the stage, an objective lens which determines the ultimate quality of the image, and an eye-piece for visual observation of the image or a projector lens for micro-photography.

In the electron microscope, these elements are replaced by corresponding electronic elements. Thus, the light source becomes an electron source, and the solid light lenses are replaced by magnetic field lenses. Structural details, however, are quite different. Since electrons are absorbed and scattered by air, it is necessary to maintain a high vacuum throughout the entire electron path. The inherent nature of electrons, which makes a vacuum necessary, also requires a special type of specimen-mounting technique. Instead of glass slides and cover glasses, a much more "transparent" medium of support is employed.

Operation of the electron microscope is appreciably different from that of the light microscope, and in many ways is much simpler and more convenient. Focusing of the electron beam is determined by the power of the objective, and is therefore controlled simply by adjusting the current flowing through the objective coil, all distances remaining fixed. Similarly, no lenses need be changed to vary the magnification, which is controlled by varying the strength of the current flowing through the projector coil.

As in the case of glass lenses in the light microscope, the electromagnetic lenses of the electron microscope are subject to such defects as aberration and diffraction. These are reduced through the use of a limiting aperture. The optimum diameter of this aperture is that for which the effects of aberration and diffraction are equal. However, in actual practice, the opening differs from this optimum value to take into account the contrast and resolution desired with different types of specimens.

STABILITY CONDITIONS OF OPERATION

The effectiveness of a magnetic electron lens depends on the value of the current flowing through the exciting coil and on the velocity of the electron beam. In order, therefore, to obtain photographic records with all of the detail present in the electron image, it is imperative that the exciting current and electron accelerating voltage remain extremely constant during the time of exposure. It is a function of the power supply circuits incorporated in the design of the RCA Electron Microscope to insure the required high degree of constancy of the energizing voltages and other operating conditions.

Disturbing factors of another nature must also be eliminated. These include the effects of varying external magnetic fields, of random electrostatic potentials accruing on partially insulating surfaces in the electron path, and of mechanical vibration due to external sources such as nearby heavy machinery, railroads and motor trucks.

Varying external magnetic fields will produce extraneous effects in the electron image but such effects have been minimized in the RCA Electron Microscope by adequate shielding of the sensitive regions. The presence of electrostatic potentials, however, constitutes a somewhat more difficult problem. It has been found that a partially carbonaceous, semi-conducting material is deposited on all of the diaphragms which are in the direct path of the electron beam. When these deposits become sufficiently heavy, the potentials at the exposed surfaces may be considerably different from that of the metal aperture. The effect is most serious in the case of the objective lens where the image defects thus introduced are sufficient to limit the resolution. At present, the simplest method of eliminating this difficulty is to replace the limiting aperture at periodic intervals. The resolution of the RCA Electron Microscope will vary from about 30 Angstrom units (equal to 30 x 10^{-7} millimeters), with a new aperture to about 100 Angstrom units at the end of one month of normal operation.

Little or no difficulty is to be expected from external mechanical vibration provided normal precautions are observed at installation. In the RCA Electron Microscope, independent displacement of any of the components of the magnification system is almost entirely overcome by rigid construction of the sensitive elements and by shock-mounting of the complete instrument.

SPECIMENS

The intensity distribution in an electron image formed by the microscope is, for the major part, due to variations in the scattering power of different portions of the specimen. In general, absorption of the electrons does not occur in the extremely thin type of specimens best suited for electron microscope observation. Such absorption actually is to be avoided since the energy released by the absorbed electrons appears as heat, and may be sufficient to raise the temperature of the specimen to a point where decomposition and structural changes may occur. It has been found, in practice, that satisfactory images will be obtained with specimens up to one micron in thickness, using electrons accelerated by potentials of the order of 50 kilovolts.

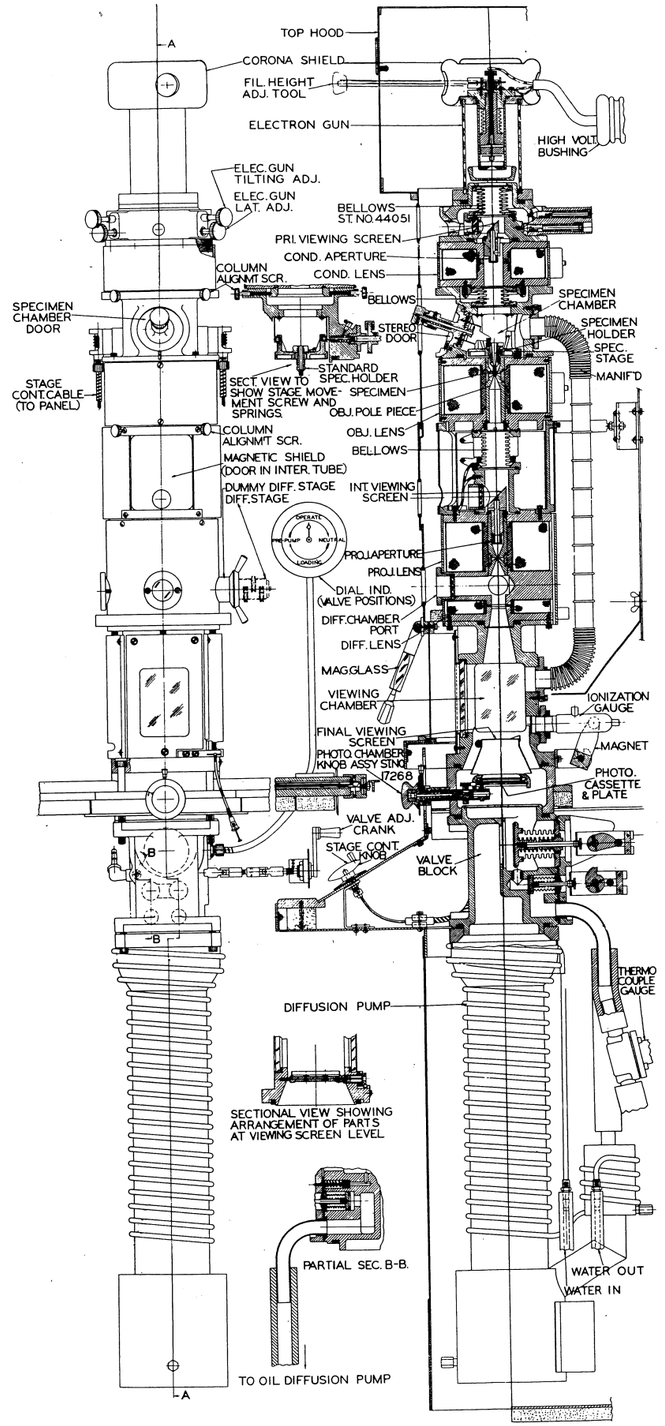


Figure 3—Electron Microscope, Outline Drawing (WW-307499—Sub. 1)

DESCRIPTION

GENERAL LAYOUT OF ELECTRON MICROSCOPE

An overall view of the RCA type EMU Electron Microscope is shown in the photograph of Figure 1. An outline diagram of the assembly is given in Figure 3. Essentially, the main body of the microscope consists of a vertical column about three feet high and six inches in diameter, made up of a number of sections which are joined together. The joints are provided with air-tight rubber gaskets, permitting the required low pressure to be obtained within the column assembly. For this purpose, the column is connected to a diffusion pump and a rotary pump.

Mounted at the top of the microscope column is the electron gun assembly which comprises a cathode or source of electrons and an anode whose potential provides the proper acceleration and direction for these electrons. Then, from top to bottom along the column, are located the condenser aperture and primary viewing screen, the magnetizing coil of the condenser aperture and primary viewing screen, the magnetizing coil of the condenser lens, the specimen chamber, objective lens coil, projector aperture and intermediate viewing screen, the projector-diffraction lens coils, the final viewing screen, and the photographic chamber. Glass windows are provided in the wall of the column to allow for examination of the images on the viewing screens. Both the specimen chamber and photographic chamber are provided with doors which may be opened when there is normal air pressure in the column so that specimens and photographic plates may be inserted into and removed from the column.

At the rear of the column assembly is a vertical cabinet which contains the necessary vacuum tubes, transformers, and other circuit elements for the generation and accurate regulation of the supply voltages which energize the electron gun and the three lens coils. Two electronic vacuum gauges are also provided, with their associated circuits, to indicate the pressure within the microscope. All operating controls are mounted on the control panel of the instrument within easy reach of the operator.

A description of these various component parts of the microscope is given in the following pages. For ease of discussion the components have been grouped according to their respective functions, a thorough understanding of which will greatly facilitate the operation of the apparatus as a whole. These groups refer respectively to the magnification system; the specimen, viewing, and photographic facilities; the vacuum system; and the electrical system.

MAGNIFICATION SYSTEM

The magnification system comprises the electron source or electron gun assembly, the condenser lens, the objective lens, the projector-diffraction lens, and associated pole pieces. These various units are described below. They are assembled through substantially cylindrical sections, with which they form the microscope body or column. The sections are provided with suitable doors, windows, aligning and centering controls, and constitute, respectively, the specimen chamber, intermediate chambers and photographic chamber.

Electron Gun—The function of the electron gun is to form the electron beam and direct it down the microscope column through the condenser lens. The electron gun consists mainly of (a) the cathode, maintained at 50 kilovolts with respect to ground and (b) the anode, at ground potential. The cathode structure supports the filament assembly (Stock No. 44511) which consists of a mica support and insulating disc, studs for supporting the actual filament, and studs to provide electrical connections. The filament itself is made up of 0.004″ diameter tungsten wire, 0.5″ long, bent in the form of a "V" with the free ends spot welded to the supporting studs. The radius of bending at the filament apex must be as small as possible, of the order of 0.005″, and the height of the filament apex with respect to the face of the mica disc should be close to 0.4″.

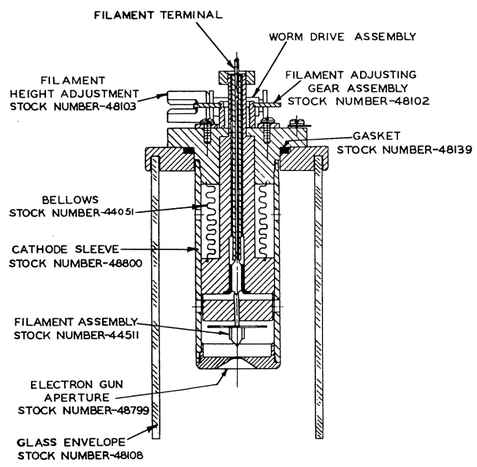


Figure 4—Electron Gun Assembly (M-439171—Sub. 1)

The electron beam is formed by electrons emitted from the apex of the "V"-shaped filament. These electrons first pass through a 0.100″ diameter aperture in the cathode shield and are then accelerated toward a $\frac{3}{16}$″ diameter aperture in the anode.

The filament assembly may be raised or lowered, along the vertical axis of the microscope, with respect to the cathode shield by inserting the

hard rubber gun adjustment tool through the hole covered by the RCA monogram on the front of the top hood. **CAUTION:** THIS ADJUSTMENT SHOULD NOT BE MADE WITH ANY TOOL OTHER THAN THAT SUPPLIED WITH THE INSTRUMENT. The pin on the end of the tool fits into a slotted cup on top of the gun assembly. Clockwise rotation of the tool lowers the filament, while counter-clockwise rotation raises the filament.

Four screws at the front of the column near the base of the gun provide angular and lateral adjustment of the gun. The upper pair of screws allow angular or "tilt" adjustment of the entire electron gun. The lower pair of screws drive the gun laterally at right angles to the axis of the column. Thus, after the electron beam has been directed parallel to the axis of the microscope by means of the "tilt" screws, the beam may then be made to coincide exactly with the aperture in the condenser lens. To facilitate the aligning of the beam with the condenser lens, a port is provided in the base of the gun assembly, through which a cross-section of the beam may be seen.

Condenser Lens—The condenser lens controls the concentration or intensity of the electron beam on the specimen. The condenser lens consists of an iron-clad coil with a gap at about the middle of the central opening. The lens is provided with an aperture 0.025″ diameter supported by a holder, the upper part of which forms the fluorescent primary viewing screen. This screen can be seen through the port in the gun assembly base. Four screws, located just below the coil, allow alignment of the condenser coil-electron gun system with the rest of the column.

Objective Lens—The objective lens, through which the electron beam passes next, forms an image (intermediate image) of the specimen in a plane just above the projector lens.

The objective lens is similar in appearance and construction to the condenser lens, except that the central opening contains a removable pole piece assembly. The objective lens forms an intermediate image, which can be viewed on the intermediate viewing screen, at a magnification of about eighty diameters. The image is focused by adjusting the objective current. To align the axis of the objective and the illuminating system with the axis of the projector, an adjustment is provided just below the objective.

Projector-Diffraction Lens—The final lens in the electron optical system is a double lens. Two separate windings and gaps make up the two lenses which are constructed on a single spool and enclosed in a single outer shell. For microscopy, only the projector coil section is energized, by turning the projector-diffraction switch to "Proj." This lens contains a removable pole piece, similar to the objective pole piece, and supports the intermediate viewing screen which also carries the 0.050″ diameter projector aperture. The projector lens magnifies the intermediate image obtained from the objective lens, and projects it on the final viewing screen for visual examination, or on the photographic plate. The magnification developed by the projector lens depends on the pole piece and the current through the projector coil.

If the instrument is used for obtaining diffraction patterns instead of micrographs, the projector lens current is turned off, and the diffraction lens current turned on in its place. The diffraction lens provides a low power focusing system for the diffracted rays.

Electrical Connections to Lens Coils—The electronic circuits of the microscope are arranged to accurately regulate the current in the lens coils, and the regulation obtains for each chosen value of current. The lens coil connector plugs should not be disconnected when the current through the lens is turned on, because this action will considerably overload the regulators and damage the coils from inductive kickback. If there is no current flow indication at the test meter for any lens circuit, the defective circuit should be turned off immediately. The regulating circuit, the connecting cable and plug, and the lens coil itself should be checked to ascertain the cause of the difficulty. In manufacture, all lens coils are tested for quality of insulation by application of 1,000 volts to ground.

Pole Pieces—Each lens contains a pole piece, specifically designed for its particular function. The inner configurations of these pole pieces, as well as other components which come in contact with the electron beam, must for proper operation be kept absolutely clean. This matter of cleanliness is treated in detail in a later section, under the heading "Cleaning Pole Pieces."

The condenser pole piece is a fixed part of the lens, and cannot be removed for cleaning. Its aperture is comparatively large, and, therefore, does not require more than routine inspection for dirt or other foreign materials.

The objective and projector pole pieces are made of brass and soft magnetic iron, and should be handled with care. In order to prevent scoring and binding of the threads when screwed tightly, a small amount of octoil is applied on the threads and bearing surfaces. Cleaning instructions are given in the maintenance section of this book.

The projector pole piece assembly is furnished with two brass spacers. If the short spacer is used there will be a gap of $\frac{3}{64}$″ between the two soft iron parts of the pole piece. This gives a magnification range from 7,500 to 22,000 diameters as the projector lens current is raised from minimum to maximum. If the long spacer is used, the gap is $\frac{19}{64}$″, and the magnification range is from 4,000 to 11,000. If no spacer is used, and only the top half of the pole piece is used, the magnification range is from 700 to 4,000. If the microscope is used with no pole piece, the magnification range is from 75 to 750.

The magnification range from 75 to 750 diameters is adequately covered with the projector pole piece removed, but distortion is quite severe in the lower part of this range. Magnifications

from 50 to 300 diameters can be obtained with very little distortion by removing the objective pole piece and using only the top half of the projector pole piece. The range from 300 to 1000 diameters may also be covered with negligible distortion by removing the objective pole piece and using the entire projector pole piece with the short spacer in it.

Under these conditions, with the objective pole piece removed, the FOCUS I control must be run near maximum current in order to obtain a sharply focused image. In many cases, the maximum current will still be inadequate to permit focusing. By simply inserting the specimen holder spacer between the specimen holder and the stage, the specimen holder will be lifted enough to permit the FOCUS I control to give a sharply focused image on the final screen.

It is clear that a number of other magnification ranges may be obtained by using different combinations of pole pieces and spacers. However, the entire range from 50 diameters to more than 20,000 can satisfactorily be covered with the combinations described. Refer to Figure 78.

Objective Aperture—For most materials, contrast will be increased through the use of the objective aperture. By eliminating a large portion of the randomly scattered electrons, which provide background effect only, resolution is enhanced.

The objective aperture is installed in the mechanical order given in Figure 33. The simplest method of assembly consists in first joining the short end of the pole piece to the brass spacer. This is followed by carefully nesting the washers, the aperture and the spring in the inner portion of the brass spacer. The long portion of the pole piece is now assembled to the free end of the brass spacer. The aperture itself is delicate and should be handled and installed with extreme care. It is of utmost importance that its orifice be absolutely clean. Instructions for cleaning are given on pages 37 and 38.

Electron Diffraction Unit—The Diffraction Unit permits the type EMU Electron Microscope to be used interchangeably as an electron diffraction camera or an electron microscope. The Diffraction Unit includes a projector lens as well as a diffraction focusing lens and means for holding and adjusting specimens for diffraction examinations. Diffraction patterns may be obtained by either reflection or transmission (powder) methods. Specimens for transmission studies are mounted and supported on standard 200 mesh screens, according to the same techniques employed for micrograph work. Reflection specimens are supported on a special holder and may have the following maximum dimensions: 0.25" square by 0.063" thick. If the reflection specimen holder is not used, slightly thicker specimens may be employed. In many cases, it is possible to produce micrographs of a given specimen and then transfer the specimen to the Diffraction Unit and obtain a diffraction pattern of the same substance on the same photographic plate.

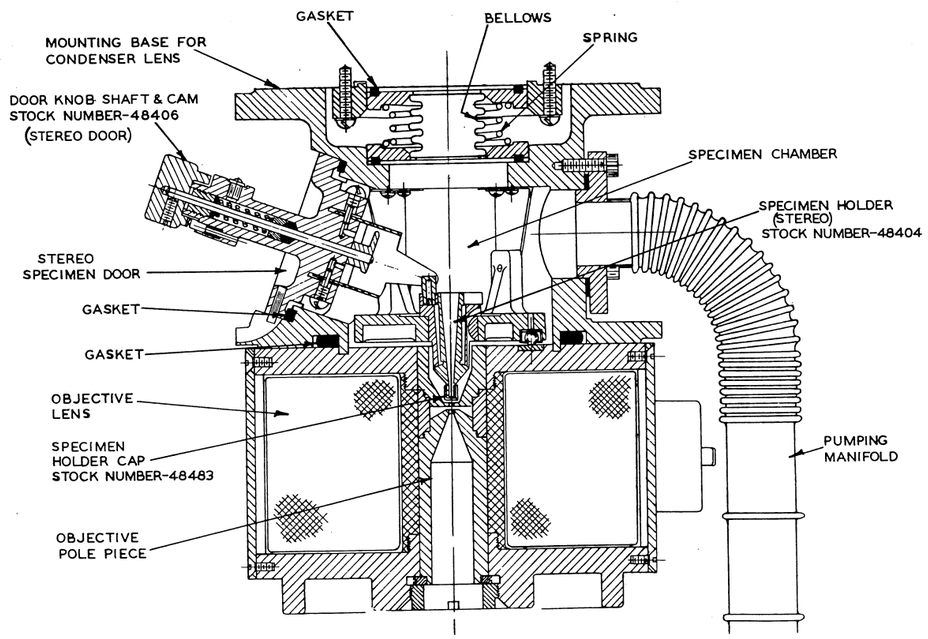


Figure 5—Specimen Chamber and Objective Lens (P-722674)

SPECIMEN VIEWING AND PHOTOGRAPHIC FACILITIES

Microscope Specimens—The specimen to be examined is inserted in the path of the electron beam between the condenser lens and the objective lens. It is mounted on an eighth-inch diameter, 200-mesh wire screen and placed in a special holder which is supported on a movable stage inside the column.

Specimen Holders—There are two types of specimen holders: the standard holder (Stock #48390) and the stereoscopic holder (Stock #48404). With each holder, the screen is inserted in the small cap, specimen side down, and then the cap is pushed onto the end of the holder as far as possible.

The standard holder is made of two pieces, one threaded into the other to allow vertical adjustment. A set screw is provided to lock the two parts together when adjusted. The holder should be adjusted in length so that when it is assembled with a specimen screen in place, the cap will clear the objective pole piece by an amount sufficient to give the greatest possible magnification consistent with free movement of the stage. This positioning is accomplished by trial and error, inserting the loaded holder and decreasing the specimen-objective distance until the movement of the image becomes erratic.

The stereo specimen holder is made in two parts: an outer part which has the same outside dimensions as the standard specimen holder, and can replace the latter in the specimen chamber; and an inner part which is a cylindrical tube with the specimen clamped at its lower end. The central axis of the outer part coincides with the incident electron beam when in operating position. The central axis of the inner part may be adjusted to coincide with the incident electron beam or to be tilted 4° on either side of the beam.

To make this adjustment, turn the handle on the specimen chamber door. The handle is connected to an internal fork that tilts the inner cylinder which carries the specimen. When the knob is turned to the right, the specimen holder is turned to the right, and conversely a turn to the left takes the holder to the left. After the holder has been placed in either position, right or left, the handle must be returned to the central position, with the control knob dot at the top. The return position prevents interference with the fork by permitting free movement of the stage and specimen holder.

Specimen Stage—Directly above the objective lens is the specimen stage within the specimen chamber. Both the specimen stage and the holder may be moved in any desired direction in the horizontal plane within the chamber by two position controls, which are connected through worm gears and flexible shafts to the two unlabeled, handwheel knobs on the control panel and are calibrated from 1 to 10.

Intermediate Image Viewing Screen—Between the objective and projector lenses are the intermediate tube and port for viewing the intermediate image. The image produced by the objective is observed on a fluorescent screen situated just above the projector. As this image is important for the alignment of the instrument, a port is provided through which the operator may observe the image.

Photographic Chamber Viewing Screen—The final image is observed on the fluorescent screen at the base of the microscope column. The viewing screen has a square marked on it which indicates the portion of the image which will be photographed if an exposure is made. The center of the screen is also marked to assist in centering images. Especially helpful in adjusting the focus of the image and providing additional magnification is a 2½ × magnifying glass, attached in front of the viewing chamber.

Photographic Chamber—The fluorescent screen is raised or lowered by an external gear control and flexible cable release. When photographic records are made, the fluorescent screen which acts as a shutter must be raised to allow the electron image to fall directly on the photographic plate immediately below. The 10" by 2" photographic plates which are used allow a series of five 2" x 2" exposures to be made, with the focus slightly changed from one exposure to the next. Thus the loading time per picture is reduced, and the ultimate resolving power of the microscope can be exploited. The exposure times vary from one to several seconds.

VACUUM SYSTEM

The electron beam, which takes the place of the light source in the Electron Microscope, requires a vacuum chamber for its existence and application. Figuratively, the RCA Electron Microscope is a cathode ray vacuum tube of large dimensions, and having but two main elements—a cathode or source of electrons, and an anode whose potential supplies the proper acceleration and direction for those electrons.

Besides dissimilarity in size, the Electron Microscope differs from the ordinary vacuum tube in many other ways. The interior of the Electron Microscope must, of necessity, be exposed to atmosphere from time to time. On the other hand, an ordinary vacuum tube is permanently sealed, and thus, conditions are ideal for obtaining and maintaining very low pressures. Outgassing of the elements and interior walls through heat, the use of "getters" (gas absorbers) and other processes tend to produce and maintain the excellent vacuum required by ordinary vacuum tubes for their applications.

The Electron Microscope has to be outgassed each time it is exposed to atmosphere, and the outgassing process becomes longer, the greater the exposure time. This is because the inner surfaces of the microscope absorb gases until sat-

uration is reached and equilibrium is established with the surrounding atmosphere. Since it is not practical to employ continuous heating or "getters" to completely outgas and maintain vacuum in a system such as the Electron Microscope, another arrangement is employed—the use of high-speed pumping. While high-speed pumping will not produce low pressures equal to those obtained by heating and "getters," it will produce a pressure low enough to be entirely satisfactory for the establishment and use of an electron beam. In other words, the high-speed pumping system removes gases at a faster continuous rate than the vacuum chamber can continually give them up and, in the process, produces the required vacuum.

The vacuum system of the Electron Microscope thus comprises (a) pumps for creating and maintaining the required vacuum within the microscope body or chamber, and (b) vacuum indicators or gauges which indicate when the internal pressure has reached a sufficiently low value to allow actual operation of the equipment. These are described in the following paragraphs. A general schematic layout of the entire vacuum system is given in Figures 6A, 6B, which show the pumps, valves and gauges with indication of their respective functions.

Pumps—As described in the preceding sections, the main body of the microscope constitutes, essentially, a large vacuum tube. It is, however, constructed in a number of sections sealed with rubber gaskets which form a vacuum seal. Furthermore, as the openings through the centers of some of the sections are extremely minute, a manifold is incorporated in the design to by-pass these small orifices. This is essentially a long, flexible tube with separate connections to the main chambers of the microscope body. The larger volumes of the microscope can thus be pumped out very quickly through the manifold. Incorporated in the diffusion pump is an aquastat which automatically disconnects the heater when an insufficiency in the water supply becomes inadequate for cooling. The outlet of the diffusion pump is connected by means of a flexible rubber hose to a mechanical fore pump.

With the mechanical fore pump in series with an oil diffusion pump, it is possible to obtain a vacuum of 10^{-4} mm. of mercury or better. The pumps are controlled by a valve block which opens and closes the valves in the proper sequence. This is operated by a crank on the right-hand side of the instrument, the position of which is shown on a dial on the front panel. The fore pressure and column pressure are indicated by meters on the control panel.

Fore Pump—The mechanical fore pump which is supplied with the microscope is a Cenco Hypervac 20, driven by a ½ H. P. motor. When the pump is put into operation, the motor draws a heavy starting current—18 to 20 amps.—but the normal operating current is about 7 amps. (115-volt service). The driving belt should be adjusted to the proper tension by moving the motor closer to or farther from the pump. If

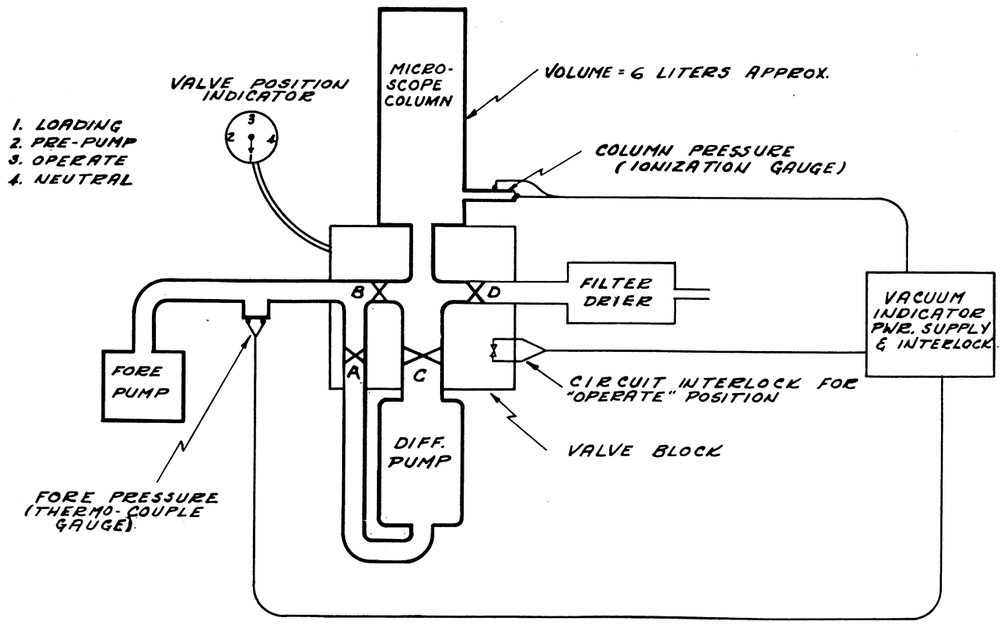


Figure 6A—Vacuum System, Simplified Schematic Layout (*M*-430516)

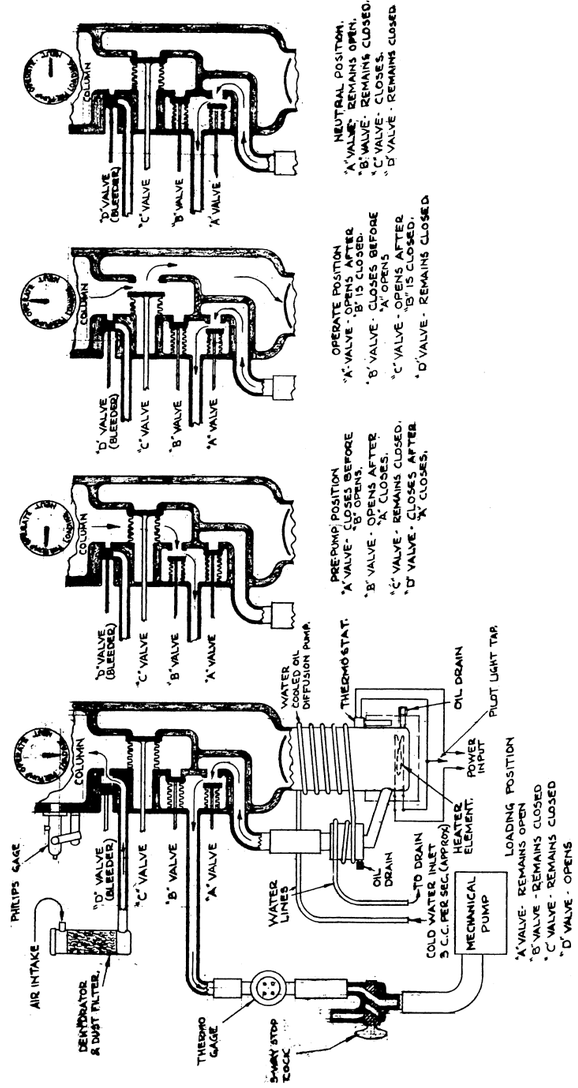


Figure 6B—Schematic of Vacuum System (*M*-427490)

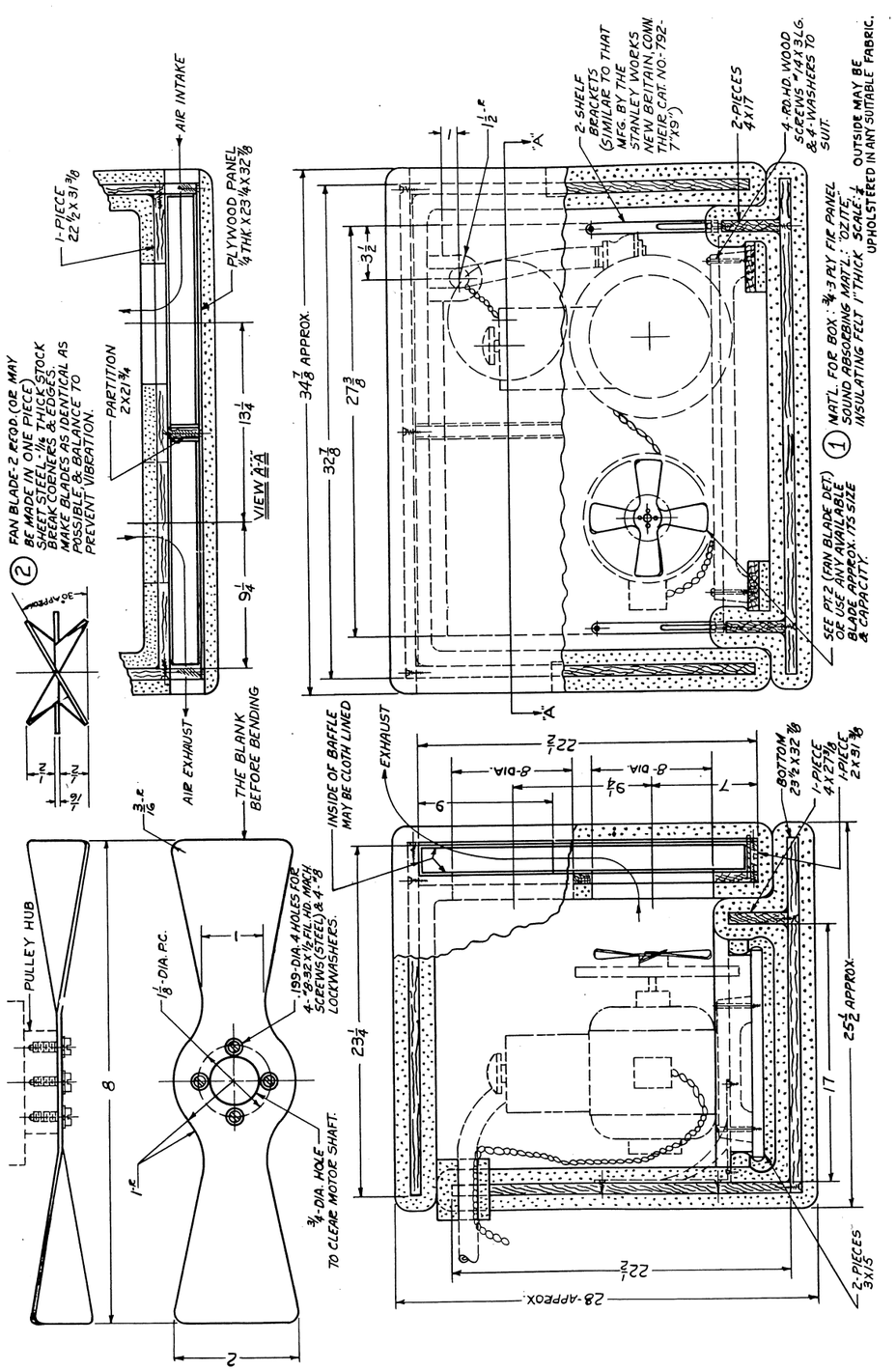


Figure 7—Noise Suppressor for Rotary Pumps (PX-277149)

the belt is too loose it will slip and burn; if it is too tight it will deliver power with low efficiency. To suppress the sound of the pump, the pump may be placed in a sound-proof hood constructed of plywood lined with ozite. Figure 7 shows a satisfactory design for this hood. It is ventilated by fan blades attached to the pump motor. Holes in the hood allow the circulation of air through it.

Fore Line—The fore pump line consists of extra heavy wall rubber connecting tubing, copper pipe as required, and a glass three-way stop-cock. With this stop-cock it is possible to connect the pump to the microscope through the fore line, seal it off from the fore line, or connect it to atmosphere. This latter connection may be used either to let air into the pump or to evacuate auxiliary apparatus when the microscope is not in operation. The stop-cock should be lubricated with a good grade of stop-cock grease. Connections in the fore line are facilitated by rubbing a **small** amount of castor oil on the inside of the hose. To obtain the greatest pumping speed, the conductance of the fore line should be as great as possible. Since the inside diameter of the line is fixed, pumping speed is enhanced by keeping the fore line length to an absolute minimum.

Diffusion Pump—The diffusion pump is a vertical oil pump with a metal casing. Tap water should be run through the cooling coil at a rate of 3 cc/sec, entering at the high vacuum end, 5-10° below room temperature and leaving the pump slightly above room temperature. The cooling water should be turned off when the pump is exposed to the atmosphere for a long period, since water vapor may condense inside the pump and contaminate the pump fluid. The heater is a 400-watt, 30-ohm unit which receives its power from the voltage stabilizer. A variable (R-112) resistor with screwdriver slot, located on the lower chassis, can be adjusted to vary the heater temperature. The most satisfactory heater current, about 3.0 amperes, should be set and small adjustments made to change the pumping speed or the fore pressure at which the diffusion pump will begin to operate.

If the power input to the diffusion pump is set at too high a value, pumping speed will not be materially improved and an audible "crackling" noise will be heard coming from the pump. If the slight vibrations caused by this "crackling" are imparted to the microscope column, poor micrographs will result. Resistor R-112 should be set so that the heat delivered to the pump is just below the point at which the "crackling" effect occurs.

The thermo-switch, S-15, located at the base of the pump, opens the heater circuit if the temperature becomes too high. The pump is adjusted while running normally with the proper heater current and water flow. The screw on the switch is turned until the circuit opens and then backed up one turn. The blue lamp, A-5, on the lower chassis, indicates that voltage is being applied to the heater.

An accidental inrush of air from the forepressure side of the pump may blow the pump jet assembly into the upper part of the pump. A spider prevents the jets from returning to the proper position at the bottom of the pump. It is, therefore, advisable to inspect the position and centering of the jets after sudden breaks in the fore pressure. To center the jets, direct a flashlight into the casing and bend the arms of the spider on top of the assembly until the clearance between the lower jet and the casing appears to be the same on all sides.

Valve Block—Four pump line valves, located in the valve block, are arranged so that the valves are operated in the proper sequence. Mechanical means prevent valving from being accomplished in the wrong direction. The operation of the valve block can be best understood from the block diagram of the vacuum system. (Figures 6A, 6B.)

The valve "A" connects the fore pump to the output of the diffusion pump; the valve "B" connects the fore pump to the microscope column; the valve "C" connects the intake of the diffusion pump to the microscope column; the valve "D" connects the column through the dehydrator (filter drier) to the atmosphere.

When the valve block is put in the "loading" position, "D" is open, letting air into the column; "B" and "C" are closed, sealing the microscope column off from the pumps; "A" is open so that the fore pump is pumping the diffusion pump. When the valve block is in "pre-pump," "A" closes and "C" remains closed, thereby sealing off the diffusion pump; "D" closes and "B" opens so that the fore pump can rough pump the column. In "operate" position, "D" remains closed; "B" closes, shutting the column off from the fore pump; "A" and "C" open, so that the forepump and diffusion pump are pumping the microscope column in series. In "neutral" the valve "C" is closed, so that the column is shut off from the pumps.

The valve positions are changed by one clockwise rotation of the crank handle on the right-hand side of the microscope below the cassette chamber. Valve position is indicated by the pointer and dial opposite the clock. When the indicator is installed, the pointer must be adjusted by turning the knurled knob on the back of the indicator dial so that the dial agrees with the valve position existing at the time.

The pumps should be started with the valves in "neutral" or "loading." The power to the diffusion pump can be turned on at the same time, as it will take about fifteen minutes to heat up. As soon as the fore pump has started, the stop-cock is turned so the fore pump is pumping on the diffusion pump. After about five minutes, the valve block is turned to "pre-pump." It is left in this position until the fore pressure has reached a value of 50 microns, as indicated by a half-scale reading on the fore pressure meter. It is then turned to "operate." The operating pressure of 5×10^{-4} mm. of mercury is indicated by a reading of 0.3 on the column pressure meter as

the current is decreasing. The glow tube above the meter is lighted on both sides when the current is increasing and on one side only if the current is decreasing.

When the microscope is in use, the pumps are run continuously, and the valve block kept in "operate" except when a specimen or plate is changed. It is turned through "neutral" to "load," to let air into the column.

When the microscope column is repumped, the forepressure must be brought down to 50 microns at "prepump" before the valve block is turned to "operate." It should be possible to pump the instrument from atmospheric to operating pressure in about one and a half minutes. When the instrument is shut down for the night, or extended periods, the valves are left in "neutral," sealing off the column. The pumps are turned off. The stop-cock in the fore line is always closed before the fore pump is turned off.

Vacuum Gauges—The microscope contains two pressure gauges which are read on the two meters on the left-hand side of the control panel. The power to the gauges is supplied by transformers, T-5 and T-9, which are wired so that the gauges will operate if either the "main power" or the "panel lights" are turned "on." The gauge circuits are described in the section on electrical circuits.

The fore pressure is measured by a thermocouple gauge located in the fore line between the stop-cock and the valve block. As the pressure is decreased, the energy radiated by the hot thermocouple is decreased, its temperature is increased, and the thermo-electric voltage and the meter reading are increased. The fore pressure meter is calibrated by adjusting R-14, on the back of the control panel until the meter M-1 reads full scale at the minimum pressure obtainable when the fore pump alone is pumping on a system free of leaks.

The column pressure is measured by a cold cathode ionization gauge located at the base of the microscope column. The gauge is a two-element tube passing a current which depends on the amount of ionization in the column. This amount of ionization is a function of pressure. The current is measured by the meter M-2 and is roughly indicated by the glow tube, V-9. As the pressure is decreased, the current rises to a maximum and then falls to about zero.

The column pressure meter is calibrated by adjusting R-12 on the back of the control panel in such a manner that when the pressure is decreased, and the meter indication rises to a maximum, and then falls back toward zero, the maximum reading will be approximately full scale.

The ionization gauge circuit is designed to close the relay, K-1, when the current falls to a value corresponding to the maximum safe operating pressure of the microscope. The relay closes the high voltage and electron gun filament circuits. If the column pressure should accidentally rise above operating pressure, the high voltage and gun circuits are automatically opened. The relay cannot operate at low ionization currents corresponding to near atmospheric pressures, because it is shorted by an interlock switch. However, this is not the case when the valves are in "operate" position.

Filter Drier—The air which is let into the column is dried and cleaned by passing it through the air filter which is located in the right-hand side of the microscope cabinet. The cleaning is accomplished by the felt pads at the ends of the filter. About once a year these should be cleaned thoroughly with a blast of air or replaced. The air is dried with "Indicating Drierite" or anhydrous calcium sulfate. If the dehydrated Drierite becomes rose colored up to the "change line," it should be replaced by dry Drierite or the pump down time of the microscope will increase because the Drierite is saturated with water vapor which can be drawn into the column. The Drierite can be regenerated by heating in an open pan in an oven or on a hot plate, at a temperature of from 200°C to 250°C from one to two hours. The Drierite should at no time be heated above 300°C (572°F). The Drierite should be agitated during the heating process because water is released from the upper surface.

CONTROL PANEL

The functions of the controls mounted on the control panel are described in accordance with the titles as engraved on the control panel.

1. **PANEL LIGHTS**—A toggle (S-3) switch supplies power to the panel lights and to the vacuum gauges and their circuits. When extreme darkness is required for image examinations, switch S-3 turns off panel illumination. The switch is interlocked with the main power switch. If the main power switch is "on" the panel lights can be turned off, but the power to the vacuum gauges and their circuits will remain "on."

When the panel lights, main power, and high voltage switches are thrown to the left, they are in the "off" position.

2. **MAIN POWER**—Through the main power switch (S-4), power is supplied to the low-voltage supplies and the vacuum gauge circuits. To operate the microscope the main power switch is thrown to the "on" position and the test meter switch is set to the "Proj" position. When the test meter has stabilized at a reading of approximately 60 (150 milliamperes actual current), all circuits have warmed up and the high-voltage switch may be turned on.

3. **HIGH VOLTAGE**—The high-voltage switch (S-8) controls the circuits which produce the 50 kv accelerated voltage. However, 50 kv can not be obtained unless the following conditions are satisfied; the main cabinet door interlocks are closed; the main power switch is closed; the cabinet hood interlock switch is closed; the valving system is in the "Operate" position; and the electronic circuits of the vacuum gauges indicate

that a sufficiently low pressure has been reached in the microscope column.

4. **ROOM LIGHTS**—The room light switch is connected to a 3-way receptacle inside the cabinet. This receptacle may be tied in with a portion of the lower room lighting and a 3-way wall switch, allowing room illumination to be controlled either from the control panel of the microscope or from the wall switch.

5. **DIFFRACTION-PROJ. SWITCH**—With this switch in the "Diff" position, the diffraction lens is operative and the current through the lens is controlled by the "Diff Focus" control. In the "off" position neither the diffraction or projection lenses are actuated. With the switch in the "Proj" position, the "magnification" control regulates the current in the projection lenses.

6. **OBJ. SWITCH**—In the "off" position, no current is fed to the objective lens. In the "on" position, the three focusing controls, Nos. 1, 2 and 3, regulate the current in the objective lens.

7. **COND. SWITCH**—In the "off" position, this switch removes current from the condensing lens. In the "on" position, it allows the "Intensity" control to regulate the current of the condensing lens.

8. **TEST SWITCH**—The test switch and its associated meter allow instantaneous checking of all the important voltages and currents in the electronic circuits.

Other controls, such as the camera cassette and shutter, specimen movement, vacuum gauges, gun filament and "beam" meter, are described in other portions of these instructions relating to the specific equipment.

POWER SUPPLY SYSTEM

WARNING: Many of the voltages used throughout the circuits of the microscope are dangerous to life. Circuit checking and trouble shooting should be performed by no fewer than two operators. Even though power has been turned off, various capacitors in these circuits are capable of storing electrical energy for considerable periods of time, at voltages which are dangerous to life. Before touching any of these circuits, they should be grounded and discharged with the "grounding rod" supplied as a part of the equipment. Tapped holes are provided on both sides of the cabinet frame where the grounding rod conductor may be securely fastened. In addition to grounding, it is good practice to test each circuit requiring examination with a voltmeter before any physical contact is made.

In order to prevent damage to the equipment, tubes should not be removed from circuits in operation. Before putting the electrical circuits into operation, the following instructions should be read carefully. Likewise, the warning given on labels on the inside of both cabinet doors should be understood.

Function of Power Supply—It is a function of the power supply system to provide from the 115-volt, 60-cycle supply line, the various alternating and continuous voltages required for the operation of the electron microscope and its associated equipment. At the same time, the electronic system insures the necessary high degree of constancy of these operating voltages.

All input power for the microscope, with the exception of the vacuum fore pump, is obtained from the voltage stabilizer. Changes in line voltage between the ranges of 95 to 130 volts are regulated to 115 volts by the line voltage stabilizer.

Location of Power Supplies—The main portion of the cabinet is divided into three sections, which permits easy access to the electronic circuits and components. The top section, containing the high-voltage unit, provides the accelerating voltage of 50 kv for the electron beam. The middle section, comprising the upper chassis, contains the required oscillators and their components. The lower section, or bottom chassis, includes the main sources of d-c power and the vacuum control circuits. The instrument control circuits are mounted on the control panel at the front of the instrument. Access to the high voltage, upper and lower chassis is obtained through the main cabinet doors. To gain access to the control panel, it is simply necessary to slide the table top forward and remove it. With the table top removed, the control panel can be tilted or disconnected and removed from the instrument for servicing.

The drawings included in this instruction book which describe the electronic circuits are as follows: block diagram Figure 8, overall schematic Figure 71.

CIRCUIT DESCRIPTION

BLOCK A—+370-Volt Regulator, Rectifier and Projector, Regulator, Plate Supply Rectifier— Block A consists of tubes V-3, V-4, V-5, V-6, V-7 and V-8, transformer T-3 and their associated components.

The function of Block A is to provide a regulated d-c voltage of 370 volts and an unregulated d-c voltage of 400 volts, both positive with respect to ground. The regulated voltage is used as plate supply for tubes in Block E (the electron gun filament oscillator), Block K (the high-voltage regulator), Block B (the projector regulator and supply) Block C (the objective regulator and supply), and in Block D (the condenser supply). The unregulated voltage is provided as a source voltage for Block B. Block A receives its power from the transformer, T-3, which has windings of 500 volts, 5 volts and 6.3 volts, and from sections No. 3 and No. 7 of T-4. The plates of both of the full wave rectifier tubes, V-3 and V-4, are supplied by the 500-volt winding of transformer T-3. The filament of V-3 is heated by the 5-volt winding of transformer T-4. The filament of Tube V-4 is heated by the 6.3 volts winding of T-3. The resistor R-1 is placed

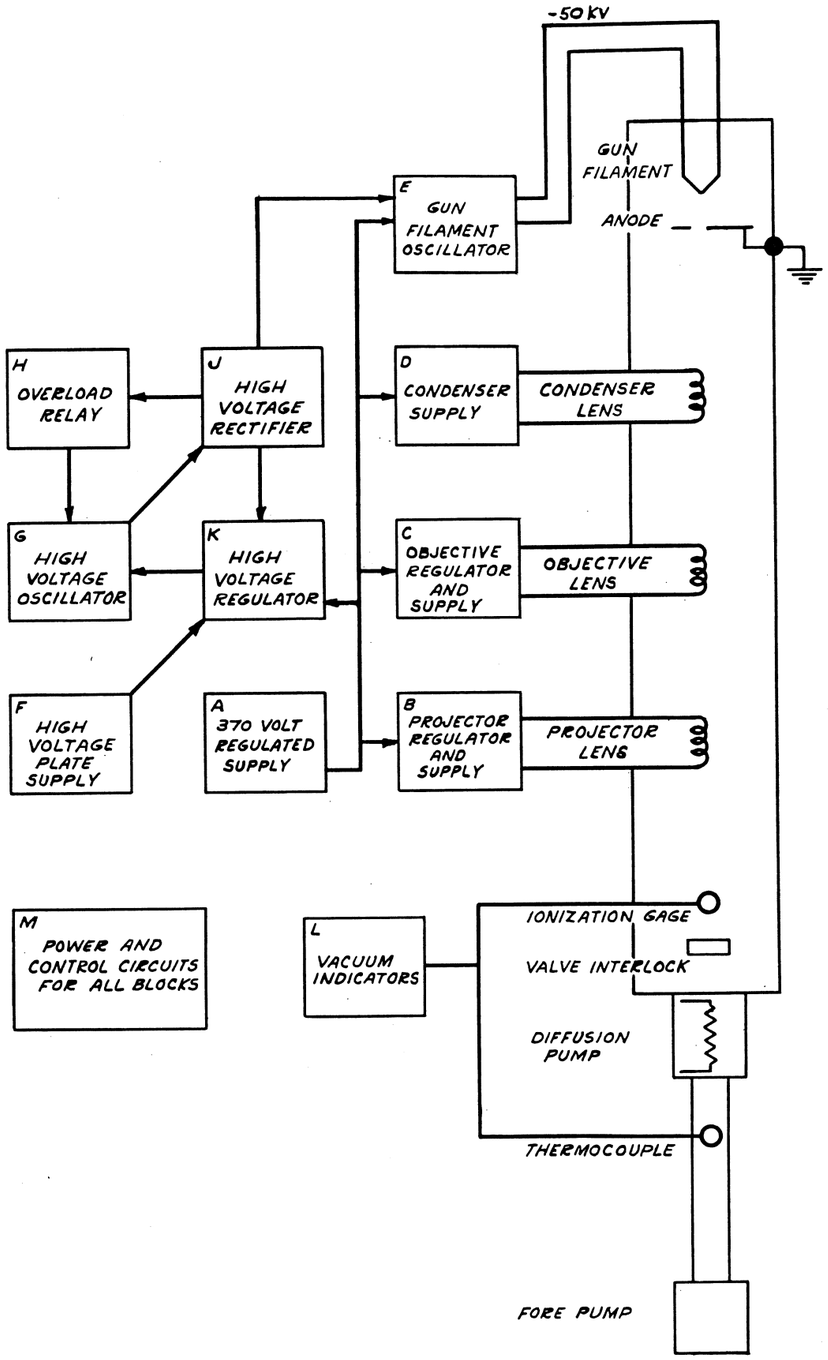


Figure 8—Electrical Block Diagram of Electron Microscope (M-427474)

in the circuit to drop the voltage for the filament of tube V-4 to 5 volts. The filaments of tubes V-7 and V-8 are heated in parallel by section No. 3 of transformer T-4 and that of tube V-6 is heated by section No. 7 of T-4.

The rectified voltage across tube V-4 is filtered by chokes L-4, L-5, and capacitors C-6, C-7, C-10 and C-11. The output, an unregulated voltage of 400 volts, is applied to the anode of tube V-14 in Block B.

The rectified voltage across tube V-3 is filtered by choke L-3 and capacitors C-4, C-5, C-8 and C-9, and fed through variable resistance tubes, V-7 and V-8, to the output capacitor, C-14. Resistors R-2 and R-8 constitute a voltage divider across the output, and part of the output voltage is coupled through resistor R-4 to the grid of tube V-6. The a-c coupling from the output to this grid is provided by capacitor C-13. The cathode of tube V-6 is maintained at a constant potential relative to ground by V-5, a constant voltage tube, in parallel with capacitor C-12. Since tube V-6 will not pass enough current to keep tube V-5 fired, an additional path for current is provided by resistors R-3 and R-62.

The output voltage of the rectifier tube, V-3, is applied as a positive potential to the anodes of tubes V-7 and V-8. The screens of these tubes are connected to the same voltage supply through dropping resistors R-6 and R-7. This tube, V-3, also supplies a positive voltage, through resistor R-5 to the anode of tube V-6. The grids of tubes V-7 and V-8 are connected in parallel and are decoupled by resistor R-9.

If the load on the regulator draws an increased current, the output voltage across capacitor C-14 will tend to decrease. This decreased output voltage will bias the grid of V-6 more negatively, causing a decrease in plate current and a rise in anode voltage. This potential increase in a positive direction is transmitted to the grids of V-7 and V-8 and allows them to pass more current. The increased current will flow through the voltage divider, raising the voltage across it and C-14. Thus the original drop in voltage, caused by the load, is compensated and the voltage is kept at a constant value.

This regulated voltage of 370 volts can be measured on the control panel test meter by turning the switch to "Reg." This connects the meter in series with the multiplier, R-72, converting it into a 1,000-volt full-scale voltmeter.

BLOCK B—Projector Regulator and Supply— This block consists of tubes V-14 and V-16, the proj.-diff. lens and the associated components and controls.

The function of Block B is to maintain a steady current through the projection or diffraction lens windings and the heaters of tubes V-16, V-22, and V-24. V-16 is part of Block B; V-24 is in Block C, the objective regulator and supply; and V-22 is in Block K, the high-voltage regulator. These filaments are heated by a regulated current in order to keep the emission of the cathodes uniform and enhance the regulating characteristics of their circuits. The current through the projection and diffraction lenses must be constant to keep the magnification constant.

Switch S-7, located on the control panel, will put either the projection coil or the diffraction coil in series with the heaters of V-16, V-22 and V-24 as the load on the regulator. In its "off" position, both coils are disconnected but the heaters continue to draw current. The projection coil is paralleled by resistors R-100, R-101, R-102, R-103, R-104, R-105, R-106, R-107, R-108, R-109, R-110, R-111, and R-114. The "Magnification" dial S-14 on the control panel is a selector switch which changes the current through the projection coil by changing the interconnections of the above mentioned resistors. Resistor R-100 keeps the coil from being shorted on the position of lowest magnification. The diffraction coil is paralleled by resistors R-24 and R-25. R-25, the "Diffraction focus" dial on the control panel, is a variable resistor which allows adjustment of the current through the coil. Resistor R-24 is shunted across the diffraction coil to prevent it from being shorted. The diffraction coil, with a resistance of 280 ohms, has in series with it resistor R-23. The combined resistances of the coil and the resistor offer approximately the same resistance to the regulator as the 634 ohms resistance of the projection coil.

A suitable load reference voltage for the input of the regulator tube, V-16, is developed across the resistors R-34 and R-17 in series with the load. R-34 can be adjusted to determine the operating current of the regulator. Capacitor C-17 provides the AC coupling from the load to the grid of tube V-16. The reference grid bias for V-16 is obtained from B-10 (45 volts) in series with the decoupling resistor, R-33, and the fuse, F-6, which protects the battery in case of shorts. The anode voltage of tube V-16 is obtained through the voltage-dropping resistor, R-28, from the 370 volts regulated supply of Block A. The anode voltage of tube V-14 is obtained from the 400-volt unregulated supply of block A. The screen and cathode of V-14 are kept at lower potentials than the anode by R-30 and R-31, respectively. The filament of tube V-14 is heated by section #4 of transformer T-4. Resistor R-32, which is in series with the load, is adjusted in conjunction with resistor R-34 to provide regulation of the output circuit at its rated value of 150 ma. This value is correct for the heaters of tubes V-16, V-22 and V-24, as well as the lens regulation circuits.

An increase in load current makes the control grid of tube V-16 more positive and the anode more negative. When the current through tube V-16 increases, the grid of tube V-14 becomes more negative, the tube passes less current and the load current returns to its normal value. The regulated current through the load is measured by turning the test meter switch to "Proj." This connects the meter in series with the load, and

shunts it with R-29, making it a 250 ma. full scale milliammeter.

BLOCK C—Objective Regulator and Supply—Block C includes tubes V-23 and V-24, the objective lens, and the associated components and controls.

The function of Block C is to maintain a steady current through the objective lens coil which has a resistance of 2630 ohms. S-12 is the objective switch on the control panel. In the "off" position, the objective coil is shorted and the resistor R-66, is substituted for it so as not to upset the stability of the regulator when the switch is turned "off" and "on." When the switch is "on," the lens coil is connected in series with resistors R-74 to R-93 inclusive. This resistance network is the coarse control of the objective current used to focus the image, and is adjusted by the "focus 1" dial on the control panel. Resistors R-64, R-19, and R-63 are in parallel with the above mentioned series resistor network. R-64 is the "focus 2" or medium control and R-19 is the "focus 3" or fine control. R-63 is a fixed resistor which keeps either branch of the focus control resistor networks from shorting the other. The reference grid bias on the control grid of the regulator input tube, V-24, is obtained from the battery B-11. The decoupling resistor, R-60, and the fuse, F-5, are connected in series with the battery in order to protect the circuit in case of short circuits. AC coupling to the control grid is provided by capacitor C-42. The anode of the series regulator tube, V-23, is supplied directly by the 370 volt regulated output of block A. The screen grid of V-23 is supplied through resistor R-56; the control grid of tube V-23 and the plate of the tube V-24, are supplied through resistor, R-58. The filament of tube V-23 is heated by section 5 of the transformer T-4, and that of the tube V-24 by block B.

When the current through the objective coil increases, the voltage on the grid of the tube V-24, becoming more positive, causes it to draw more current. The voltage on the plate of the tube V-24 and the grid of V-23 decreases. The tube V-23, therefore, passes a lower current through the load, compensating for the original increase. The regulated current is measured by turning the test meter switch to "obj." which connects the meter across resistor R-61. The meter then becomes a 250 ma. full scale milliammeter in series with the objective coil.

BLOCK D—Condenser Supply—Block D consists of the condenser lens and its associated controls.

The function of Block D is to supply a regulated current at some chosen value through the condenser lens coil, having a resistance of 9440 ohms. In the "off" position of the condenser switch, S-5, the condenser coil is shorted; in the "on" position of the switch S-5, the coil is connected through rheostat, R-21; to the 370-volt regulated supply of Block A. The movable tap is used to adjust the current through the condenser coil by changing the resistance in series with it. This is the "intensity" dial on the control panel. The current, limited by resistor R-22, is measured by turning the test meter switch to "cond." The test meter, in series with the load and with R-61 shunting it, is converted into a 25 ma. full scale milliammeter.

BLOCK E—Gun Filament Oscillator — This block consists of tube V-27, transformer T-10 and the associated controls and components.

The function of Block E is to heat the electron gun filament. An alternating current source of about 185 KC transfers power to the filament circuit by inductive coupling. It thus isolates the supply source from the high d-c voltage on the gun filament. Insulation is thereby simplified and the number of points at which high voltage has to appear are reduced.

The RF voltage to supply the filament is generated by a Colpitts oscillator, tube V-27. The anode is supplied through the choke coil L-10 and resistor R-70 from the 370-volt regulated supply of Block A. This voltage is disconnected by the vacuum interlock of block L if the pressure in the column is not low enough to operate the microscope. Resistor R-70, marked "gun filament" dial on the control panel, controls the output of the oscillator by changing the plate voltage. The choke L-10 and capacitor C-39 prevent RF current from being fed into the plate supply. Capacitor C-38 is a by-pass condenser for the screen grid resistor R-69.

The cathode is grounded through resistor R-68, a test meter shunt. When the meter switch is turned to "Fil," the meter connected across resistor R-68, becomes a 250 ma. full scale milliammeter which reads the anode current of the oscillator. Capacitor C-37 by-passes the RF current from the meter. The heater of the oscillator tube is supplied by transformer T-8.

The power is transferred to the gun filament by the transformer T-10. A grounded electrostatic shield prevents the secondary of the transformer T-10 from picking up voltages from the 75 KC high voltage oscillator or from other stray fields. The resistors, R-44 and R-45, form a balanced network for the gun filament. Resistor R-43 is a surge resistor which protects the high voltage rectifiers in case of an overload in the microscope.

BLOCK F—High Voltage Oscillator Plate Rectifier—This block contains the rectifier tubes V-1 and V-2, the transformers T-1 and T-2 and the associated filter circuit.

The function of Block F is to supply the DC voltage for the plates of the oscillator tubes of the nigh voltage oscillator, Block G. The power for Block F is supplied by the transformer, T-1 which has a secondary voltage of 1180 volts and transformer, T-2, which has a secondary voltage of 5 volts. The filaments of the tubes V-1 and V-2 are heated by the transformer T-2. The rectified voltage is filtered by the chokes L-1 and

L-2, and the capacitors C-1, C-2, and C-3. The 1250-volt d-c output of the rectifier tube is fed to the plates of the tubes V-15, V-17, and V-20 in Block K, the high voltage regulator, and to the plates of the tubes V-18 and V-19 in Block G, the high voltage oscillator.

BLOCK G—High Voltage Oscillator—Block G includes the tubes V-18 and V-19, oscillator transformer L-8 and related circuit components.

The function of Block G is to provide a high alternating voltage which is rectified and applied to the gun filament to establish the electron beam. The voltage is generated at 75 KC by a modified form of Hartley oscillator in which the output is taken from the coil of a series resonant circuit in series with the oscillator coil.

The two oscillator tubes, V-18 and V-19, are connected in parallel. R-39 is the decoupling resistor between the grids and R-38 is the decoupling resistor between the plates. The d-c plate voltage is supplied by block F through the resistor, R-95, in block K, the high voltage regulator circuit. The choke L-9 and the capacitor, C-22, keep the RF current out of the d-c supply. The resistor R-37 is a multiplier to convert the test meter into a 1000-volt voltmeter. When the meter switch is on "OSC. Voltage" it measures the d-c plate voltage on the oscillator tubes. The filaments of the tubes, V-18 and V-19, are heated by the transformer T-7. The capacitors, C-18 and C-19, by-pass the RF current around the transformer T-7 which would otherwise present a high impedance. The grid bias is obtained from current through the resistor R-41, by-passed by the capacitor C-21 to prevent negative feedback. The resistor, R-40, is a meter shunt to convert the test meter into a 250 ma. milliammeter. When the meter switch is on "OSC. Current" it measures the d-c anode current of the oscillator. C-20 by-passes the RF current from the meter. One end of the feedback coil, L-8, is connected to the grid through the capacitor C-21. The other end is grounded through the capacitor C-20. The tap of the coil, L-8, is connected to the center tap of the filament transformer, T-7. When an overload occurs, this point is grounded by the relay, and oscillation ceases. The return circuit from ground to the plate is through block J, the high voltage rectifier. To the oscillator, the equivalent circuit of block J is that of a series resonant circuit, resonant at 75 KC. About 17,000 volts appear across the coil, L-13, the coil of the series resonant circuit in block J.

BLOCK H—Overload Relay—This block includes relay K-2, meter M-3, tubes V-25 and V-26 and associated circuit parts.

By automatically turning off the high voltage, Block H protects various circuits when the beam current becomes too high. If the current exceeds one milliampere the relay will short part of the feedback coil of the high voltage oscillator and stop oscillation.

In normal operation, the return path of the beam current from ground to Block J, the high voltage rectifier, is through the relay, K-2; meter M-3; and resistors, R-54 and R-55. The meter M-3 on the control is the beam current meter panel. When on the control the beam current becomes excessive, the voltage across the resistor, R-54, fires the tube, V-26, which carries most of the current and protects the meter. The resistor, R-55, is a surge resistor to distribute the voltage in case of a sudden overload. The resistors, R-56 and R-57, provide a path in parallel with the relay K-2. The resistors R-42 and R-53 provide a locking path for the relay, if it is operated. The capacitor C-36 and the resistor R-56 protect the relay contacts.

When the beam current is high enough to operate the relay, K-2, the relay grounds the center tap of the feedback coil (L-8) of the high voltage oscillator tube.

The relay also connects the tube V-25 and resistor R-56 in series, the resistors R-42 and R-53 across the plate supply of the high voltage oscillator, causing the tube V-25 to fire. The tube V-25 is the overload indicator on the control panel. Current also flows through the resistor R-57, to hold relay K-2 in its overload position. This current will keep the relay in its overload position after the beam current has been turned off. The relay returns to its normal position when the high voltage switch (S-8) is turned off.

BLOCK J—High Voltage Rectifier and Tripler—This block includes tubes V-28, V-29 and V-30, transformers L-13, T-12 and T-13 and required circuit components.

The function of Block J is to maintain a negative d-c voltage of 50,000 volts with respect to ground on the electron gun filament. The anode of the microscope, which is grounded, can then accelerate the electrons emitted by the filament. The r-f voltage from Block G, the high-voltage oscillator, is rectified and tripled by Block J.

An r-f voltage of approximately 17,000 volts appears across coil L-13. C-44 is a coupling condenser to the oscillator, Block G. The filament of the tube V-28 is heated by the transformer T-4. It is put at ground potential for high frequencies by the capacitor C-31, which also by-passes r-f from the overload relay system. The filaments of the tubes V-29 and V-30 are heated by the transformers T-12 and T-13.

When the plate of V-29 receives a positive voltage from the transformer L-13, it conducts, charging the capacitor C-30. On the next half cycle, the voltage across the coil L-13 and the voltage across the capacitor C-30 are in series and the plate of the tube V-28 is positive. When the tube V-28 conducts, it discharges the capacitor C-30 and charges the capacitors C-26 and C-27 in series to the sum of the voltage across the coil, L-13 and the capacitor, C-30. In the next half cycle, the tube, V-29, conducts, recharging the capacitor C-30. At the same time the tube

V-30 conducts charging the capacitor, C-28. (For simplicity of description, the operation of V-30 up to this point has been omitted.) The voltage across the capacitor C-28 is in series with that across the capacitors C-26 and C-27, so that after several cycles, the capacitor C-29 is charged to 50,000 volts, the sum of the voltages across the capacitors C-26, C-27 and C-28. The negative high voltage is connected to the gun filament by the surge resistor, R-43. The bleeder resistor, R-65, in series with the resistor R-52, acts as a voltage divider across the high voltage. The voltage across the resistor R-52 is applied to the grid of the tube V-22 in Block K, which regulates the high voltage. The coil L-15, and the capacitors C-29, C-23 and C-24 constitute a wave trap for the ripple frequency of the high voltage. They constitute a series resonant circuit which presents a low impedance to 75 kc. and by-passes it from the load, the microscope. When either of the side doors is opened, the capacitors C-26, C-27, C-28, C-29 and C-30 are mechanically grounded and discharged.

BLOCK K—High Voltage Regulator Circuit—This block includes the tubes V-15, V-17, V-20, V-21 and V-22 and their associated circuit components.

The function of Block K is to regulate the high voltage. When the beam current increases, it tends to make the high voltage decrease. Block K increases the plate voltage of the high-voltage oscillator tubes in Block J; the high voltage increases and is restored to its normal value.

The plate voltages of the series regulator tubes, V-17 and V-15, are obtained from the 1,250-volt output of Block F, the high-voltage plate supply rectifier. The control grid voltage of the tube V-17 is also obtained from the above mentioned plate supply through the voltage dropping resistor, R-35. The screen grid voltage of V-17 is obtained from a tap on the resistor R-95. The grid of the tube V-15, which is connected to the anode of the tube V-17, is biased by the resistor R-36. R-15, R-96 and R-97 are decoupling resistors to prevent parasitic oscillations. The filaments of the tubes V-17 and V-15 are heated in parallel by section No. 2 of the transformer T-4.

The plate voltage of the tube V-20 is obtained from the 1,250-volt supply through the resistor R-35. The screen voltage is obtained through the resistor R-46 from the 370-volt supply of Block A. The control grid of the tube V-20 and the anode of the tube V-22 are supplied through the resistor R-48 from the 370-volt supply. The cathode of the tube V-20 is maintained at constant potential by the tube V-21. Additional current is supplied through the resistors, R-46 and R-47, to keep the tube V-21 fired. The bypass capacitors C-33 and C-34 prevent negative feedback to the screen grids of the tubes V-22 and V-20. The screen voltage of the tube V-22 is obtained from V-21 through the voltage dropping resistor, R-50. The filament of the tube V-20 is heated by section #6 of the transformer T-4. The filament of the tube V-22 is part of the load of Block B, the projector regulator supply. R-18, R-94 and R-98 are decoupling resistors. The control grid voltage of the tube V-22 is the algebraic sum of the voltages of the batteries B-1 to B-9 in series with that part of the output voltage which appears across the comparing resistor, R-52. The fuse F-4 protects the batteries and the resistor R-52 in case of overload. The resistors R-49 and R-51, and the capacitors C-32 and C-35 are filter circuits which prevent spurious oscillation in the regulating circuits.

If the beam current increases, the high voltage and the voltage across the resistor R-52 will tend to decrease. The grid of the tube V-22 will become more positive and draw more current through the resistor R-48. The voltage on the plate of the tube V-22 decreases and the grid of the tube V-20 becomes more negative. The tube V-20 draws less current through the resistor R-35, making the anode of the tube V-20 and the grid of the tube V-17 more positive. As the tube V-17 draws more current it causes its cathode and the grid of the tube V-15 to become more positive. The tube V-15 draws more current, making its cathode more positive. This point is connected to the anodes of the tubes V-18 and V-19, in Block G, the high-voltage oscillator. This increase in plate voltage increases the amplitude of the oscillator and raises the high voltage, thus maintaining the high voltage at a constant level.

BLOCK L—Vacuum Indicators—This block includes the tubes V-9, V-10, V-11, V-12 and V-13, meters M-1 and M-2, transformer T-5 and other associated components.

The function of Block L is to indicate the pressure in the column of the microscope, the pressure in the fore pump line and to control the vacuum interlock circuits for the high voltage.

The fore pressure is indicated by the thermocouple gauge. The hot junction of the thermocouple (V-12) is located between the fore pump and the diffusion pump. The thermoelectric voltage is applied across M-1, the fore pressure indicator on the control panel. The junction is heated by the 5-volt section of the transformer T-9. The resistor, R-14, is in series with the thermocouple heater to determine the current through it and can be adjusted to make a convenient maximum reading on M-1. As the pressure in the microscope becomes lower, the amount of heat lost by the thermocouple becomes lower and its temperature becomes higher. The thermoelectric voltage increases and the reading of M-1 is higher.

The column pressure is indicated by the ionization gauge, V-13, which is located at the base of the microscope column. The gauge consists of a cathode and an anode which are located between the poles of a magnet. The magnet lengthens the path of an electron between the

cathode and anode, increasing its ionization possibilities and making the gauge effective at lower pressure. The voltage to operate the gauge is supplied by the 2,150-volt transformer, T-5. M-2, the column pressure meter on the control panel, measures the ionization current. R-12 is a variable shunt resistor on the meter M-2, to adjust its maximum reading to full scale. The capacitor C-15 by-passes a-c current from the meter M-2. The resistor R-10 limits the current through ionization gauge V-13. The transformer T-6 transmits the current variations to the vacuum interlock circuit. V-9 is an auxiliary indicator on the control panel, and shows column pressure conditions as a rough check on the meter M-2.

The a-c current and the a-c component of the rectified current are transmitted by the transformer T-6, to the full wave rectifier tube V-10. The secondary voltage is applied to the cathodes of the rectifier tube V-10, and the load on the tube V-10 consists of the resistor R-16 and the capacitor C-16, which by-passes a-c current. The d-c voltage across the resistor R-16 is applied to the grid of the amplifier tube V-11. The filaments of the tubes V-11 and V-10 are heated in parallel by the 6.3-volt section of the transformer T-9. The load of the tube V-11 is the relay, K-1, and the current limiting resistor R-20, which can be adjusted to determine the pressure at which the relay operates.

When the valve block is set in "pre-pump" position, the valve interlock switch S-6 shorts the relay K-1 so that it cannot operate until the valves are in "operate" position. As the current through the transformer T-6 decreases, the negative grid bias on the tube V-11 decreases and the plate current increases. When the pressure is low enough, the current through the relay will close the high voltage and the gun filament oscillator circuits. There will also be a high anode current at pressures near atmospheric, but the relay, shorted by S-6, cannot operate under this condition.

BLOCK M—Power Supply and Control Circuits—The function of Block M is to supply power to all the blocks.

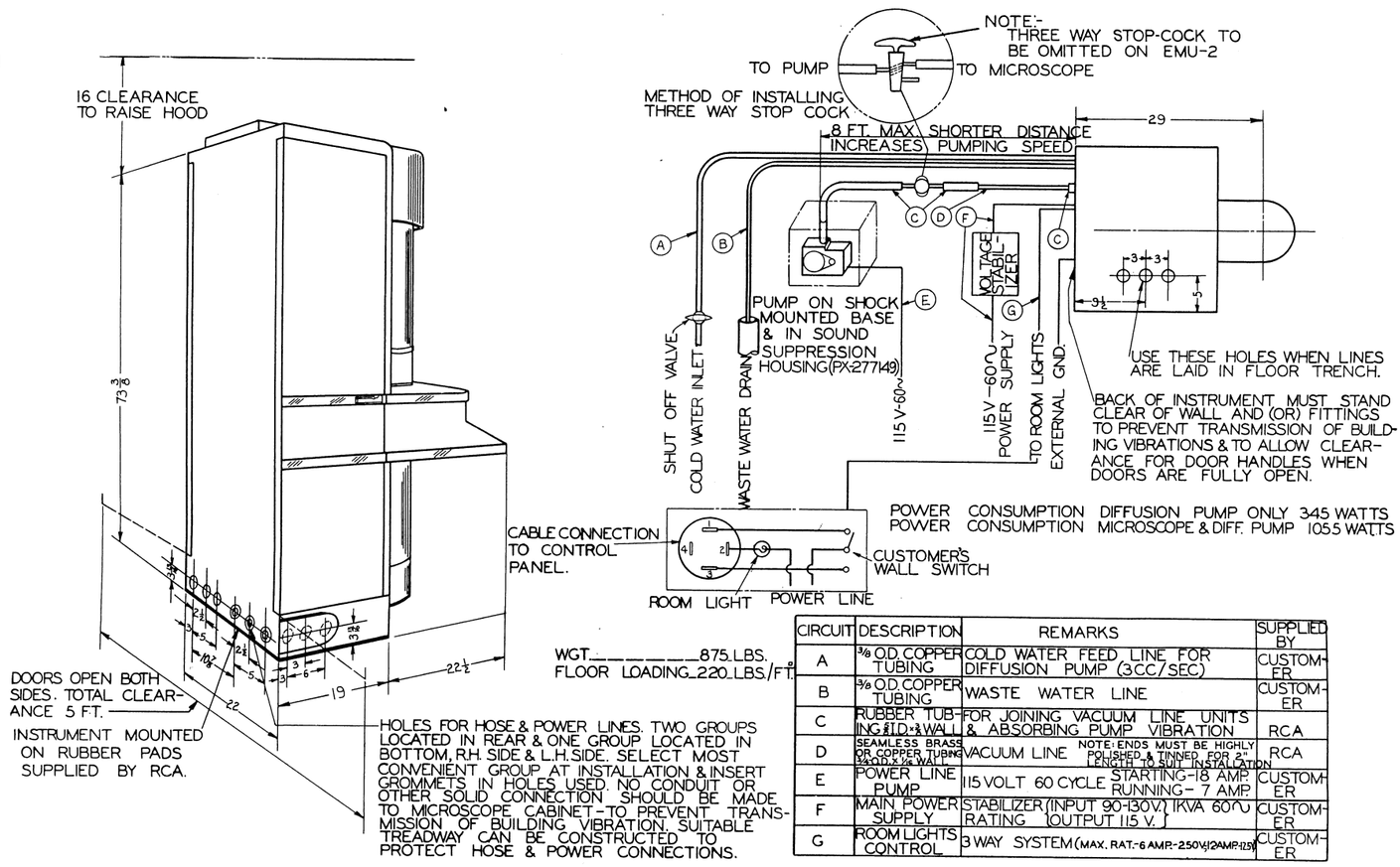
The power for the vacuum fore pump is obtained directly from the 115-volt, 60-cycle line. All other a-c power for the microscope is supplied through the voltage stabilizer transformer T-14, and the fuses F-1 and F-2. The heater of the diffusion pump in series with switch S-15 and the resistors R-112 and R-113 is connected across the output of the transformer T-14. S-15 is a thermoswitch which will open if the pump becomes too hot. The resistors R-112 and R-113 limit the current through the heater. The resistor R-112 can also be adjusted to determine the temperature of the heater for optimum pumping speed. A-5 is a lamp connected directly across the heater to indicate when voltage is applied to the diffusion pump heater. Both the fore pump and the diffusion pump operate independently of any controls on the microscope control panel.

S-1, S-2, S-17 and S-18 are interlock switches which open with the side doors of the microscope. Opening either door will turn off all exterior power to the microscope except to the fore pump and diffusion pump. Resistors R-26, R-27, R-71 and R-73 are in series with A-1, A-2, A-3 and A-4, the lights on the control panel, and drop the line voltage to the proper amount. S-3, the panel light switch, connects the lights and the transformers T-5 and T-9 across the line voltage. S-4, the main power switch, connects the transformers T-5, T-9, T-3, T-2, T-8, T-7, T-4 and T-1 across the line voltage. The transformers T-5 and T-9 supply Block L, the vacuum indicators. These circuits will operate with either the panel lights or the main power turned "on."

The transformer T-3 supplies the power for Block A and is protected by F-7 in case of a short in either of the tubes V-3 or V-4. The transformer T-2 heats the filaments of the rectifier tubes in Block F. The transformer T-8 heats the filament of the oscillator tube in Block E. The transformer T-7 heats the filaments of the oscillator tubes in Block G. The transformer T-4 heats the filaments of most of the regulator tubes. The power for Block F, the high-voltage plate supply rectifier, is supplied by the transformer T-1. This transformer has three switches in series with it so that when the main power switch is turned on it will not be connected automatically. S-8 is the high-voltage switch on the control panel. S-10 is the interlock switch which opens the circuit when the top hood is raised. The third switch is controlled by the relay, K-1, and will not close unless the pressure is sufficiently low.

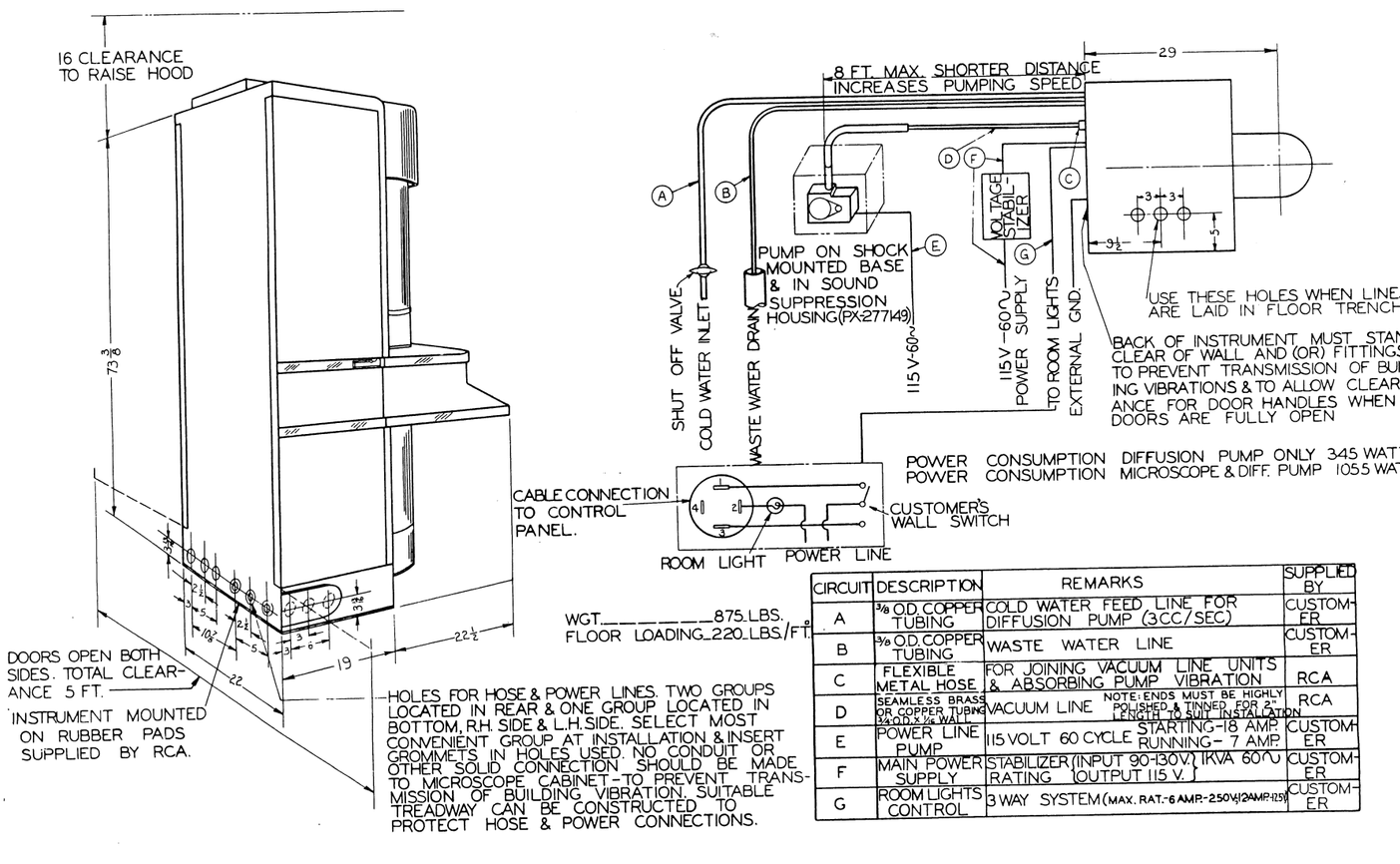
The test meter M-4 is a 1,000-ohm, 1-ma., d-c instrument. Its negative terminal is grounded and the positive terminal is connected to the selector switch S-11, so that it can be used to measure the current through the condenser lens, the objective lens or the projector lens, the cathode current of the gun filament oscillator or the high-voltage oscillator, the regulated voltage output of Block A, or the plate voltage of the high-voltage oscillator.

The switch S-13 is a double-throw switch which can be connected to the room lights so that they can be turned on and off from the control panel of the microscope.



CIRCUIT	DESCRIPTION	REMARKS	SUPPLIED BY
A	⅜ O.D. COPPER TUBING	COLD WATER FEED LINE FOR DIFFUSION PUMP (3CC/SEC)	CUSTOMER
B	⅜ O.D. COPPER TUBING	WASTE WATER LINE	CUSTOMER
C	RUBBER TUBING ⅜ I.D. × ⅛ WALL	FOR JOINING VACUUM LINE UNITS & ABSORBING PUMP VIBRATION	RCA
D	SEAMLESS BRASS OR COPPER TUBING ⅜ O.D. × .035 WALL	VACUUM LINE NOTE: ENDS MUST BE HIGHLY POLISHED & TINNED FOR 2" LENGTH TO SUIT INSTALLATION	RCA
E	POWER LINE PUMP	115 VOLT 60 CYCLE STARTING - 18 AMP. RUNNING - 7 AMP.	CUSTOMER
F	MAIN POWER SUPPLY	STABILIZER (INPUT 90-130 V.) 1 KVA 60~ RATING (OUTPUT 115 V.)	CUSTOMER
G	ROOM LIGHTS CONTROL	3 WAY SYSTEM (MAX. RAT. - 6 AMP. - 250 V. ½ 2 AMP. 125 V.)	CUSTOMER

Figure 9A—Installation Layout, Electron Microscope, Types EMU-1 and EMU-2 (P-719100—Sub. 2)



CIRCUIT	DESCRIPTION	REMARKS	SUPPLIED BY
A	⅜ O.D. COPPER TUBING	COLD WATER FEED LINE FOR DIFFUSION PUMP (3CC/SEC)	CUSTOMER
B	⅜ O.D. COPPER TUBING	WASTE WATER LINE	CUSTOMER
C	FLEXIBLE METAL HOSE	FOR JOINING VACUUM LINE UNITS & ABSORBING PUMP VIBRATION	RCA
D	SEAMLESS BRASS OR COPPER TUBING ⅜ O.D. × .035 WALL	VACUUM LINE NOTE: ENDS MUST BE HIGHLY POLISHED & TINNED FOR 2" LENGTH TO SUIT INSTALLATION	RCA
E	POWER LINE PUMP	115 VOLT 60 CYCLE STARTING - 18 AMP. RUNNING - 7 AMP.	CUSTOMER
F	MAIN POWER SUPPLY	STABILIZER (INPUT 90-130 V.) 1 KVA 60~ RATING (OUTPUT 115 V.)	CUSTOMER
G	ROOM LIGHTS CONTROL	3 WAY SYSTEM (MAX. RAT. - 6 AMP. - 250 V. ½ 2 AMP. 125 V.)	CUSTOMER

Figure 9B—Installation Layout, Electron Microscope, Type EMU-2A (P-722958—Sub. 0)

INSTALLATION

The electron microscope is dismantled sectionally at the factory and shipped in a number of individual crates. Because the microscope is to be assembled and installed only by experienced personnel, no detailed instructions are given here. The directions for reassembling after regular maintenance work has been done will be given in the "Maintenance" section of this book. However, a few general directions should be followed. An overall installation layout is given in Figure 9. This should be followed as closely as possible.

UNPACKING

A number of precautions should be observed when the microscope is being unpacked. Such precautions are:

a. Avoid using excessive force with heavy tools such as crowbars, hammers, etc.

b. All parts, after they are unpacked, should be set carefully in a safe place where there will be no danger of tipping or falling.

c. Do not handle the fluorescent screens and bellows.

ASSEMBLY

Locate the base of the electron microscope on a reasonably level floor, conveniently near water and electrical outlets.

Turn the back of the electron microscope toward a window. This arrangement allows a sufficient amount of natural light in the room and, at the same time, the cabinet acts as a light shield during the course of operation. However, it should be possible to darken the room if necessary.

Although the instrument is shock-mounted, as an additional precaution, the site chosen for the microscope should be reasonably free from externally caused vibrations, and not within a strong variable magnetic field. It will be found convenient to have a photographic dark room in the immediate vicinity of the room in which the microscope is installed.

INSTALLATION OF ROTARY PUMPS

The preferred approximate location of the main and auxiliary pumps is shown in the overall installation layout, Figure 9. The care to be given the pumps before placing them in operation, as well as during actual service, is described in detail in the "Maintenance" section of this Instruction Book.

It is recommended that the pumps be installed in a sound-proof housing. The housing detailed in Figure 7 consists of a strong box built of ¾-inch, 3-ply panels securely nailed together. It is equipped with a forced draft ventilation system to which must be attached a fan blade such as the one detailed in the drawing.

It will be noted that the box is completely lined inside and covered outside with one-inch thick "Ozite" insulating felt, or similar sound absorbing upholstery. For successful operation the box must be completely covered as shown. Most of the noise is absorbed by the inside layer of "Ozite." Very little sound can reach the wood and cause it to resonate. What little sound does get through the wood is almost completely absorbed by the outside covering of "Ozite."

One-inch long shingle nails or staples may be used to hold the "Ozite" in place. For the inside layer, glue is best since it would increase the damping effect of the "Ozite" relative to the woodwork. However, gluing leads to apparent difficulties. Joining of the various pieces of "Ozite" shown in the drawing is arbitrary. Continuous pieces are not necessary as long as the joints are pushed closely together. Certain joints may be improved by basting them together with ordinary string and darning needle.

USE OF THREE-WAY STOP-COCK WITH ROTARY PUMPS

The EMU-1 microscope is equipped with a 3-way glass stop-cock for sealing the lines from the rotary pump. The 3-way stop-cock is of the type which permits a main orifice to be connected to, or completely shut off from, either one of the two pump channels.

EXTERNAL CONNECTIONS

The external connections of the vacuum and water lines and of the electric cables depend on the particular conditions of each individual installation. Reference should be made to the installation layout, Figure 9.

OPERATION

TYPE EMU

ELECTRON MICROSCOPES

WARNING

PLEASE READ THESE INSTRUCTIONS CAREFULLY

1—WHEN EITHER THE RIGHT OR LEFT CABINET DOOR IS OPENED, ALL POWER IS REMOVED FROM THE CHASSIS AND OTHER UNITS, **EXCEPT** THE FOLLOWING:
- A–115 VOLTS A.C. FROM VOLTAGE STABILIZER THROUGH LOWER CHASSIS TO DIFFUSION PUMP—AS INDICATED IN SCHEMATIC.
- B–385 VOLTS, 45 VOLTS AND 22½ VOLTS (D.C. BATTERY SUPPLIES) FROM BATTERY ON LEFT CABINET DOOR TO UPPER CHASSIS, AND
- C–"ROOM LIGHTING" POWER (IF CONVENIENCE SWITCH IS USED) FROM LOCAL ROOM POWER SOURCE TO "ROOM LIGHTS" SWITCH ON CONTROL PANEL.

2—TO REMOVE **ALL** POWER FROM THE CHASSIS OR COMPONENT PARTS OF THE MICROSCOPE, DO THE FOLLOWING IN THE ORDER SHOWN:
- A–SHUT OFF POWER INPUT TO VOLTAGE STABILIZER (VALVING SYSTEM SHOULD BE IN "NEUTRAL" OR "LOADING" POSITION,—SEE INSTRUCTION BOOK).
- B–OPEN LEFT CABINET DOOR AND DISCONNECT BATTERY SUPPLY CABLE FROM BATTERY SUPPLY BOX.
- C–OPEN RIGHT CABINET DOOR AND DISCONNECT "ROOM LIGHTING" CABLE BY SEPARATING MALE AND FEMALE CONNECTORS. (NOTE: IF TEMPORARY CONTINUANCE OF ROOM LIGHTING IS REQUIRED, INSERT "SHORTING" PLUG FIXTURE, SUPPLIED WITH MICROSCOPE ACCESSORIES, INTO FEMALE CONNECTOR OF ROOM LIGHTING POWER FEED CABLE).

3—**BEFORE** HANDLING ANY PART OF THE **HIGH VOLTAGE CHASSIS,** DO THE FOLLOWING:
- A–INSPECT AUTOMATIC GROUNDING MECHANISM. THIS DEVICE CAUSES THREE RODS TO FALL AGAINST VOLTAGE STORING CIRCUITS OF THE HIGH VOLTAGE CHASSIS WHEN EITHER OR BOTH OF THE CABINET DOORS ARE OPENED AND THEREBY NEUTRALIZES THE VOLTAGES.

4—**ALWAYS** CHECK THE CABLE OF THE **GROUNDING ROD** BEFORE USE. THE CABLE SHOULD BE CONTINUOUS AND IT SHOULD BE SECURELY FASTENED TO THE FRAME OF THE MICROSCOPE.

5—**ALWAYS** USE THE CONDUCTING END OF THE **GROUNDING ROD** TO NEUTRALIZE VOLTAGES BEFORE MAKING PHYSICAL CONTACT. IT IS GOOD PRACTICE TO LEAVE THE GROUNDING ROD HOOKED OVER AN ELECTRICALLY CONDUCTING SURFACE OF ANY PART BEING CHECKED OR HANDLED.

6—RAISING THE **TOP HOOD** OF THE MICROSCOPE OPERATES THE FOLLOWING:
- A–AN INTERLOCK WHICH OPENS THE POWER SUPPLY FEED TO THE HIGH VOLTAGE CHASSIS.
- B–AN AUTOMATIC GROUNDING BAR WHICH NEUTRALIZES THE VOLTAGE WHICH MAY BE STORED IN THE CIRCUIT TO THE ELECTRON GUN.

7—**BEFORE** TOUCHING ANY OF THE **ELECTRON GUN** COMPONENTS WHICH ARE EXPOSED WHEN THE TOP HOOD IS RAISED, **ALWAYS** HOOK THE GROUNDING ROD ON SOME CONVENIENT METAL PORTION OF THE ELECTRON GUN HIGH VOLTAGE CIRCUIT, I.E., ANY POINT BETWEEN THE END OF GUN TRANSFORMER UP TO AND INCLUDING THE CORONA RING AT THE TOP OF THE GUN.

8—**BEFORE** REMOVING THE **CONSOLE SHELF** TO EXAMINE THE **CONTROL PANEL,** PERFORM AND EXERCISE THE SAFETY PRECAUTIONS OUTLINED IN PARAGRAPH NO. 2 ABOVE. REMOVAL OF THE CONSOLE SHELF **DOES NOT** ACTUATE ANY PROTECTIVE INTERLOCKS.

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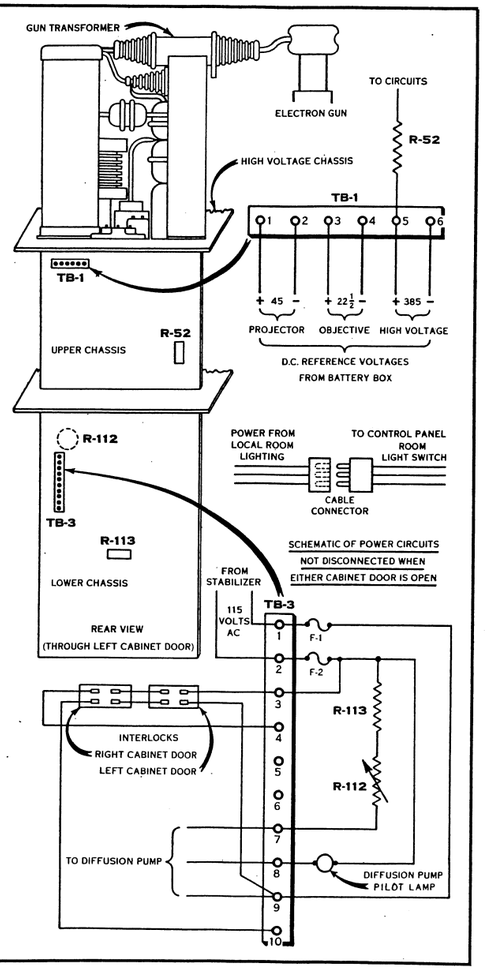


OPERATION

The operation of the electron microscope is simple after the fundamental concepts of design have become familiar. It is suggested for this reason that the operator should read the foregoing sections before attempting to operate the instrument. In the remainder of this section, the subject matter will be divided with respect to the three forms of technique involved in operation. These techniques pertain to the excitation of the instrument, the handling of specimens and the procurement of electron micrographs.

WARNING—Operation of the electron microscope involves the use of voltages which are dangerous to life. Do not change tubes or make adjustments inside the equipment with the high voltages "ON."

EXCITATION TECHNIQUE

In energizing the electron microscope, there are three major factors to be considered and properly coordinated before electron images can be viewed or photographed. First, a vacuum of the order of 0.5 micron (5×10^{-4} mm. of mercury) or better must be obtained in the large column of the microscope; second, the excitation voltages must be applied to the electron gun and field lens coils of the magnification system; and third, the electron beam must be correctly aligned with the microscope axis and focused to obtain the desired type of illumination.

OBTAINING BEAM AND IMAGE—The following procedure should be observed in evacuating the microscope column:

1. Throw the "MAIN POWER" and "HIGH VOLTAGE" toggle switches to the "OFF" (left) position. Make certain that both cabinet doors are closed and the top hood is down.

2. Throw the "PANEL LIGHTS" toggle switch "ON" (right). The position of the "ROOM LIGHTS" switch is optional.

3. Turn the crank handle on the side of the microscope till the dial reads "LOADING."

4. Turn on the power to the line voltage stabilizer and fore pump. Then turn stop-cock so the fore pump is pumping the diffusion pump.

5. The diffusion pump will take ten to twenty minutes to "warm up." During this time the "FORE PRESSURE" meter reading will rise. As the diffusion pump warms up, the "FORE PRESSURE" meter reading may decrease slightly.

6. After about 5 minutes, turn the valve control (the crank handle on the side of the microscope) to "PRE-PUMP" position. The "FORE PRESSURE" meter reading will drop near zero and then rise again.

NOTE—The meters are calibrated at the factory; no further adjustment is necessary.

7. When the "FORE PRESSURE" meter reads "50" and the "COLUMN PRESSURE" meter reading, rising, reaches "5," advance the valve control to "OPERATE" position. The "COLUMN PRESSURE" meter reading will continue to rise as the diffusion pump warms up until maximum reading approaches full scale. When the diffusion pump is heated and begins to operate, the "COLUMN PRESSURE" meter reading will decrease.

8. When the "COLUMN PRESSURE" reading decreases to "3" a satisfactory pressure in the column has been reached.

9. Turn on the "MAIN POWER" switch on the control panel.

10. When the "TEST" meter reading settles at 60 with the meter switch in "PROJ" position, turn on the "HIGH VOLTAGE." The "BEAM" meter current reading should be about .05 in a few seconds' time.

11. If the "OVERLOAD" lamp lights, throw the "HIGH VOLTAGE" switch to "OFF" (left) position, wait a few seconds and turn "HIGH VOLTAGE" on again.

12. Advance "GUN FILAMENT" control until the "BEAM" current meter reads between .2 and .5.

13. Adjust the specimen, electron gun and "INTENSITY" controls until the image appears on the intermediate and final viewing screens.

14. Check position of lens switches for the type of operation desired.

ALIGNMENT OF ELECTRON BEAM—The following description applies to a step-by-step procedure for aligning the microscope column to obtain proper performance of the instrument. It is presumed, of course, that all parts of the instrument have been thoroughly cleaned and adjusted as described earlier.

1. **FILAMENT FOCUSING (COARSE)**—The action is observed at the primary viewing screen. The condenser, objective and projector lens settings are arbitrary. The specimen holder and objective aperture are not used.

Lower the electron gun filament by means of the adjusting tool provided with the instrument. Rotate the tool clockwise to lower the filament. At some low position of the filament an astroid will appear as shown in Figure 10(1). The rotational position of the astroid is arbitrary.

Raise the filament by counterclockwise rotation of the adjusting tool. The filament image will go through the sequences 2, 3 and 4 as shown in Figure 10. At the required height, the astroid form disappears and the image is blurred. The tilt screws of the electron gun are now adjusted to permit the filament image to disappear into the hole in the primary viewing screen.

2. **OBTAINING THE BEAM**—The action is observed at the intermediate screen. The condenser lens current is set to approximately 23

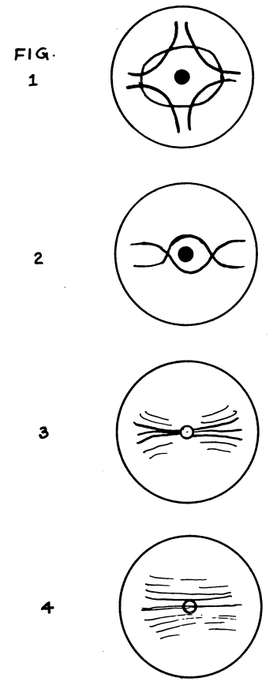


Figure 10—*Electron Gun Filament Images* (*KX*-387581)

ma. The objective lens current is set to approximately 30 ma. The projector setting is arbitrary. The specimen holder and objective aperture are not used.

The condenser lens is approximately centered by eye. The electron gun is moved laterally until illumination is obtained on the intermediate screen.

3. **FILAMENT FOCUSING (FINE)** — The action is observed on the intermediate screen. The condenser, objective and projector lenses currents are set as in the preceding step (2). The specimen holder and objective aperture are not used.

The condenser current is reduced slowly from a high value until the illumination is seen to move off the intermediate screen. Illumination is brought back by lateral adjustment of the electron gun. Continue reducing the condenser current and readjusting the lateral screws if necessary until maximum intensity and minimum spot size are obtained. This condition of the condenser is known as condenser focus or "crossover."

The height of the electron gun is varied with the filament height adjusting tool until the central bright spot is about 1/4" long as seen on the intermediate screen. Any bright areas or reflections surrounding the central bright spot may be observed by lowering the objective current slightly. If the bright filament image is not in the center of the pattern, tilting of the electron gun followed by a compensating lateral adjustment should accomplish the desired result.

Figure 11—*Adjustment of Electron Gun Height*

4. **OBJECTIVE-PROJECTOR LENS ALIGNMENT (COARSE)**—The action is observed on the final screen. The condenser is focused for maximum illumination. The objective current is set to its focal value with a specimen in position. The magnification control is set to Step 1 with the short projector pole piece spacer. The specimen holder with a suitable specimen is used. The objective aperture is omitted.

A focused image of the specimen is obtained. The objective current is varied by means of the "Focus 2" Control, and the apparent center of rotation of the final image is located. The center of image rotation is moved to the center of the screen by transverse adjustment of the objective lens. The center of rotation of the image may be off the screen by several inches and as a result may not be illuminated. Transverse motion of the electron gun is used to keep the illumination on the screen.

If the center of rotation of the image does not remain at a fixed point in the image as the objective current is changed from the focal value, the center of rotation near focus is used as the criterion for adjustment.

Under some circumstances, it may be found that the objective lens has been moved laterally in a given direction as far as possible without allowing the apparent center of rotation of the image to be brought on the final viewing screen. In this case, rotation of the objective pole piece through an angle of 180° about its axis in the objective coil will allow the mechanical and electrical axes to more nearly coincide, and thereby permit proper alignment.

5. **CONDENSER-OBJECTIVE ALIGNMENT**—The action is observed on the final screen. The condenser current is set to some high value. The magnification control is set at Step 1 with the short projector pole piece spacer. The specimen holder is used with a suitable specimen in position. The objective aperture is omitted.

Observe the image on the final screen as the objective current is reduced from its focal value. That portion of the image which moves off the final screen is returned by lateral adjustment of the condenser lens. This adjustment is continued until the lowest objective current is reached. Repeat adjustments (4) and (5) until the part of the image near the center of rotation at focus appears at the center of the screen for the lowest and focal values of objective current, and wanders a minimum amount for intermediate values. Compensating lateral adjustment of the electron gun may be necessary during the above procedures. On final adjustment, the center of rotation of the image should not wander more than a centimeter from the center of the screen as the Focus 2 knob is given a complete rotation.

6. **GUN ALIGNMENT**—The final check on gun alignment is obtained by observing the image of a suitable specimen on the final screen with the condenser focused for maximum intensity, and the magnification control set to Step 1 with the short spacer in the projector pole piece. As the objective current is decreased from focus, the image on the final screen should blur out equally in all directions. Two distinct images which appear as the objective current is decreased from focus, and which merge when the objective is refocused, indicate the need for slight further gun tilt, lateral or filament height adjustment, or a combination of all three.

SPECIMEN TECHNIQUE

The following paragraphs are a discussion on the technique in three stages, namely, insertion, examination, and removal of the specimen.

Insertion of Specimen—Before a specimen can be examined in the electron microscope it must be properly prepared and placed in one of the specimen holders supplied with the equipment. The preparation of specimens is outlined in a later section. The standard and stereoscopic holders are described in the section on viewing and photographic facilities.

The standard holder is adjustable over a range of 22,000 diameters. The method for obtaining these various adjustments is discussed under the paragraph on "Pole Pieces."

Because the stereo-holder needs room to be tilted, the holder must be set higher than the standard holder. This arrangement causes a slight loss in magnification.

As described later, the specimen is prepared on a supporting screen, about 1/8 inch diameter, made of fine metal mesh. To place this screen into the specimen holder (standard or stereoscopic type) proceed as follows:

(1) Remove the cap from the small tubular (lower) end of the specimen holder body.

(2) Place the specimen screen into the cap.

(3) Insert the lower tubular end of the holder body into the cap.

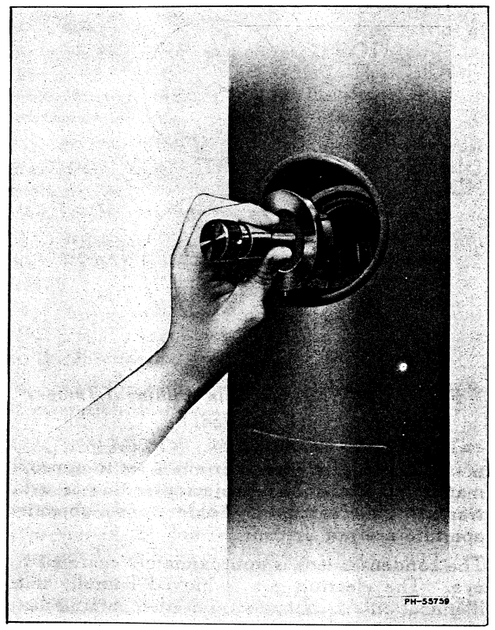


Figure 12—Removal or Installation of Stereo Door

The holder is now ready to be placed into the specimen chamber of the microscope. This is done as follows:

(1) Allow air to fill the microscope column, by turning the handcrank on the right-hand side of the microscope into the "loading" position, as shown on the dial on the right.

(2) Filling of the microscope with air to outside pressure will require approximately one minute.

(3) The door of the specimen chamber, located on the front of the microscope column can now be opened by simply lifting it off the specimen chamber opening.

(4) Place the specimen holder into the special scissors tongs provided for the purpose. These tongs have two small stud grips which fit into corresponding holes in the body of the specimen holder. The holder should be held so that the cap is at the bottom, and the keyway in the holder body oriented toward the rear of the microscope, away from the operator.

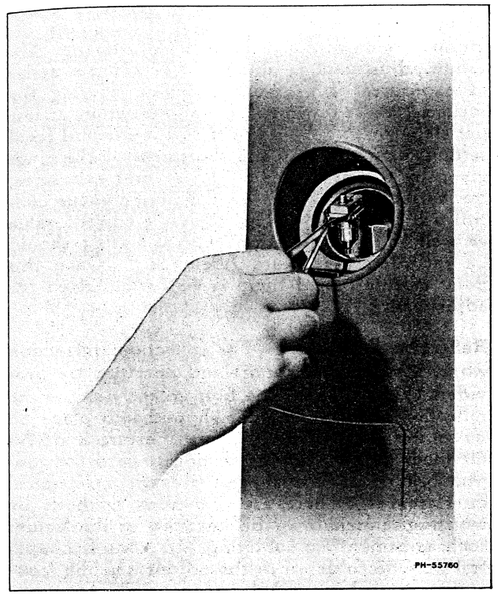


Figure 13—Insertion of Specimen Holder

(5) Through the specimen chamber door opening, insert the holder into the pole piece orifice, rocking it gently so that the keyway in the holder will engage with a corresponding key in the pole piece orifice. The holder will then fall into place, and the tongs can be released. Do not use force during this operation.

(6) In case of the stereo-holder, place this into the neutral (center) position, and place the stereo-door knob also in neutral position (this is indicated by a small mark on the door knob, which must point upward).

(7) Close the specimen chamber by placing the door over the door opening. When the stereo-door is used, its keyway (notch) must be oriented toward the bottom, to match a corresponding key at the bottom of the specimen chamber door opening. The door will be held firmly in place over the door opening as soon as vacuum has again been obtained within the microscope column.

Viewing and Examination of Specimen—When the specimen holder is inserted it is directly in the path of the electron beam. Because of the relatively low degree of magnification at this point, a large portion of the specimen is within the field of observation, and this entire field may be explored for interest value.

Two remote crank knobs on the panel of the instrument control the alignment of that portion of the specimen which is to be used in final magnification and as a subject for photography.

To remove the specimen, turn the crank handle on the side of the instrument till the dial reads "loading" to admit air into the column. After about one minute has elapsed the door can be easily removed. The holder is withdrawn with the forceps, carefully, as it was inserted. Do not use force.

ELECTRON DIFFRACTION WORK

In diffraction work, column alignment is of prime importance, particularly electron gun focusing. Incorrect gun focusing is apt to produce multiple images in the diffraction pattern. Proper alignment insures optimum patterns and aids in securing maximum intensity, a condition which diffraction technique requires.

The condenser and its control are employed as in regular micrograph work for the control of beam intensity. The objective lens and its controls are used to produce a properly located image of the source of the electrons with respect to the specimen. To set the electrical circuits for typical diffraction work, the procedure is as follows:

1. Turn on main power.
2. Turn on high voltage—50 kv.
3. Regulate beam current to about 400 microamps.
4. Set switch S-7 in "DIFF." position.

The above described routine covers the normal electrical circuit set-up, with the exception of the objective lens and the settings of its controls.

Transmission Diffraction—To produce a transmission diffraction, the following steps should be followed:

1. Prepare specimen, using standard specimen screen as supporting means. Good test patterns may be obtained from the smoke of zinc burned in an oxygen flame, or magnesium burned in air. The proper amount of smoke to be collected on the screen is a compromise between the quantity generally acceptable for micrograph work and a quantity almost sufficient to make the screen appear opaque to light. This note on quantity of specimen applies equally well to all transmission studies. Test specimens may also be prepared from suitable, preferably highly crystalline substances, using any of the regular screen and film methods of specimen preparation. In addition to the oxide smokes mentioned above, two materials which produce excellent sharp rings for focusing control adjustment are Attapulgus Clay and Montmorillonite.

2. The prepared screen and specimen are mounted in the removable cap of the transmission holder, Figure 44. The removable cap is mechanically the same as the cap of the regular micrograph specimen holder and may be used

interchangeably with it. The aperture of the transmission holder requires the strict cleanliness demanded by any other units in the electron beam axis system. In diffraction work no objective aperture is required.

3. The loaded holder is placed in the holder seat of the universal stage so that the aperture faces the electron source. It is convenient to have the control bridge of the reflection holder mechanism in a vertical position so that it is out of the way. The "ANG" adjustment wheel will provide this condition. Likewise, the reflection holder should be removed, and its control shaft drawn out of the way by means of the "TR" adjusting wheel.

4. The electrical circuits are set up as described previously and the objective lens current is adjusted to a value of approximately 5 ma. (coarse control 2). The electron gun and condenser lens are adjusted to give maximum intensity of the source image through the aperture of the intermediate viewing screen. While the condenser lens is being adjusted for maximum intensity, a series of concentric rings forming the diffraction pattern should appear on the final viewing screen. The procedure of this paragraph is intended for test and alignment purposes only, and, of course, may be employed at any time for visual check of column or specimen conditions. Patterns may not always be evident, however, due to insufficient image intensity. Image intensity is a function of the density of the specimen and its crystalline characteristics. Diffraction patterns are photographed at a different value of objective current as described in the following paragraph.

5. Diffraction patterns are photographed at an objective lens current of about 30 ma. With this higher value of objective current, the intensity of the pattern is greatly reduced as compared to that obtained at lower objective current. In most cases, the pattern rings will not be evident. However, a small spot image of the undiffracted beam will be clearly visible. The brightness of this spot can be varied by changing the condenser lens current. In photographing a diffraction pattern, it is generally best to obtain all the illumination possible without, however, using the condenser control at the point where maximum illumination is obtained. The optimum setting of the condenser control, taking into account the intensity of the diffraction pattern, is at a point slightly off maximum intensity.

Photographic exposures may require from 15 to 45 seconds depending on the intensity of the pattern. A small amount of experience with the beam spot brightness will readily disclose proper time exposure values. Standard 2 x 10 medium lantern slide plates are regularly used for diffraction pattern photography although special conditions may warrant experiment with emulsions of greater contrast characteristics. Since diffraction patterns possess a very wide range of contrast values, contact printing or enlarging requires special attention for optimum results.

Adjustment of the "DIFF. FOCUS" control is obtained by the following procedures: the diffraction focus control is varied through its entire range while observing the electron beam spot. It will be noted that the spot reaches a minimum size somewhere in the mid-range of the focus control. Moving the diffraction focus control in either direction will then tend to enlarge the size of the beam spot. The point of minimum dimension is close to correct focal adjustment. Absolute adjustment is obtained by taking a series of exposures of a given specimen, varying the focus setting a few steps (one graduation or less per step) on either side of the experimental focal setting. By studying the sharpness of the rings given by the negatives of the several exposures, the correct setting for the diffraction focus control will be found. (The objective current value as well as the diffraction control setting should be recorded for future reference.) Once this point is determined there is no further need for adjustment.

Reflection Diffraction—For reflection diffraction work, a specimen support and aperture are provided (Figure 42). The bottom view shows the reflection specimen holder slipped into place on its control shaft. The reflection aperture is always mounted with its sloping section toward the control bridge mechanism to prevent mechanical interferences. There are numerous methods by which specimens may be fastened to the holder such as cementing, soldering, etc. A soft copper foil may be soldered to the holder and the loose ends wrapped around the edges of the specimen to hold it in place. Other designs of support may be required for special applications. These can be easily turned from brass, the dimensions of interest being the hold for the control shaft which should be 0.045″ journal finish and the spring type saw slot which should be 0.015″ wide. In other cases, specimens may be mounted directly on the control shaft and the holder omitted. In these instances, the specimen is drilled about half way through with an 0.052″ drill and the specimen slipped on the shaft, using thin copper foil as a binding wedge. The smokes of metallic oxides can be collected on the reflection holder front surface and patterns obtained. This is simply to show that certain materials may be readily examined by either transmission or reflection techniques and may suggest alternate methods of obtaining patterns under special conditions for problem materials.

The electrical circuit routine is identical for transmission and reflection studies.

Figure 42 shows the universal stage and its three hand-wheels which are used to control specimen positioning for reflection studies. The control "TR" moves the specimen in a direction normal to the electron beam axis or into and out of the beam in a lateral direction. The control "ROT" permits the specimen to be rotated continuously about the axis of its control shaft. The control "ANG" permits rotation of the specimen about an axis which is normal to the control shaft axis.

All three controls are capable of independent or simultaneous manipulation, and the three freedoms of movement provided thereby, permit the electron beam to strike the crystal lamellae at any desired angle. The following data relate to the mechanical specification of the reflection specimen controls.

1. TR—Transverse

total movement	0.125″
total turns	4
thread pitch	40
dial index	25 divisions
each division	0.001

2. ROT—Rotary

total movement	360°
total turns	continuous
dial index	72 divisions
each division	5°

3. ANG—Angular

total movement	±8°
total turns	4
thread pitch	32
dial index	40 divisions
each division	0.1°

Assuming that the reflection specimen holder and specimen are in a plane parallel to the beam (angular control adjusted so that control bridge is at right angles to universal holder axis) the specimen is advanced into the electron beam until it appears to be about half-way through it, as judged by the beam spot or the half diffraction rings, if visible. The rotary and angular controls are now adjusted until maximum brightness of the half-ring pattern is obtained. The above-described adjustments are made at the prescribed low value of objective current to simplify pattern location and to obtain proper crystal orientation. Once the brightest half-ring pattern is found, the objective lens may be restored to its higher or operating value of objective lens current. While making changes in the specimen position by means of the angular and rotary controls, it may be necessary to make slight changes in the transverse adjustment so that the electron beam is continually producing full-dimensioned, semicircular patterns. When the dimensions indices of the control wheels for crystal plane studies are used, proper allowance must be made for the small amount of mechanical play existing at the control wheel bearings.

During either transmission or reflection work the "DIFF-PROJ" switch may be thrown to the "PROJ" position. In the case of transmission patterns, a small shadowgraph will appear on the viewing screen, showing the portion of the specimen screen and its contents employed in the diffraction study. The shadowgraph will tend to disclose whether or not the specimen distribution and density are suitable for the desired results. The shadowgraph of the reflection specimen on the viewing screen will disclose the location of the specimen with respect to the electron beam axis and will sometimes aid in positioning a particular portion of the specimen to the exclusion of others.

General Notes on Diffraction Work—The dummy stage Figure 41 has been designed for two purposes, namely, (1) to provide a seal for the microscope column when the universal stage is not in use and (2) to provide a fixture for special studies. Through the combination of the dummy plug and other fittings which may be substituted for the front viewing port, it is possible to provide means for spraying a specimen undergoing diffraction observation with low velocity electrons and thereby reduce the electrostatic charge assumed by certain materials; means for mechanically agitating the surfaces of various materials thereby preventing surface contamination, oxides, etc., from contributing to the diffraction pattern; means for evaporating materials so that their patterns may be obtained after evaporation, etc.

Concerning the preparation of metal surfaces for diffraction studies, reference should be made to the contents of the bibliography listed below as well as other publications relating to the same subject.

1. Thompson and Cochrane
   Theory and Practice of Electron Diffraction
   Macmillan and Co.
   New York
   1939

2. Clark
   Applied X-rays
   McGraw-Hill Book Co.
   New York
   1940

3. Reviews of Modern Physics
   Volume 8, No. 3
   July, 1936

4. Journal of the Optical Society of America
   Volume 30, No. 9
   September, 1940

5. Hillier, Baker and Zworykin
   A Diffraction Adaptor for the Electron Microscope
   Journal of Applied Physics
   Volume 13, No. 9—571-577
   September, 1942

6. Hanawalt, Rinn and Frewel
   Chemical Analysis by X-ray Diffraction
   Industrial and Engineering Chemistry
   Pub. 11A—538—Volume 10—No. 9
   September, 1938

7. Transactions of the Faraday Society
   Volume 31—Part 9a, pp. 1043-1136
   September, 1935

8. Picard
   Studies with the Electron Microscope Diffraction Adaptor
   Journal of Applied Physics
   Volume 15, No. 9—678-684
   September, 1944

The American Society of Testing Materials can supply an excellent card file—"X-ray Diffraction Data" which reveals lattice spacings and relative intensity data of several hundreds of chemical substances and compounds. This index is practically an indispensable reference for diffraction studies and analyses.

Calibration of the diffraction unit can be made by photographing a pattern of a material for which the lattice spacings are accurately known. Measurements are then made by means of a microdensitometer and the diameter of the brightest ring obtained. The brightest ring diameter is converted to Angstrom units and substituted for D in the following equation:

$$D \times d_{hkl} = K_1$$

where d_{hkl} is the known lattice spacing for the brightest ring of the chosen standard material. K_1 then becomes an instrumental constant corresponding to the fixed electrical and mechanical conditions under which the pattern data were obtained. Thus, the lattice spacings for an unknown substance may be computed, using the measured ring diameters in the decreasing order of their relative intensity from

$$d_{hkl} = \frac{K_1}{D}$$

The above formulae are a direct consequence of the Bragg law: $n\lambda = 2\, d_{hkl} \sin\theta$ and hold for small angles only, such as are encountered in the Diffraction Unit. The constant K_1 is determined by the dimensions of the diffraction camera and the wavelength associated with the electrons. K_1 will remain a suitable calibration constant for the fixed values of accelerating voltage and objective and diffraction lens currents under which the calibration data were obtained. However, since these voltages and currents are dependent on dry cell batteries for their constancy, it is advisable to re-check the calibration constant (K_1) at least once a month.

Figure 14 is an enlargement of a typical diffraction pattern (gold evaporated on supporting film).

Two spurious effects may be encountered in diffraction studies. The first is caused by the diffraction pattern given by the supporting medium used in transmission techniques. This effect is described in detail on page 1057 of reference No. 7 given above. The second effect is produced by the light given off by the gun filament. Under proper conditions of high beam current and long exposure the photographic film will be sensitized and a central spot will be produced, which should not be confused with the patterns produced by the beam itself.

The reflection specimen adjustment control shafts are sealed against atmospheric pressure by means of a rubber grommet type of seal. The two rubber seals are prelubricated before shipment and will, from time to time, require additional lubrication. The lubrication point is identified as "Lubrication" on Figure 42. Ample space has been provided to set up a proper head of lubricant. The recommended lubricant is a mixture of octoil and graphite—about ten to twenty parts of octoil to one of graphite, thoroughly emulsified.

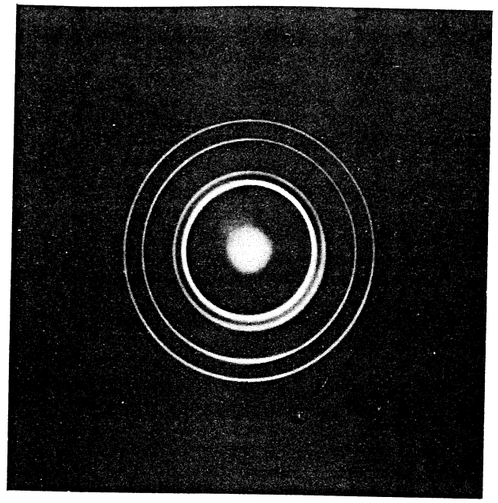


Figure 14—Typical Diffraction Pattern of Gold

Distance transmission specimen to photographic plate—10.265 in. = 261 mm.

Distance center of reflection specimen to photographic plate—10.140 in. = 258 mm.

ELECTRON MICROGRAPH TECHNIQUE

Electron micrograph technique deals exclusively with procedures involved in photographing a specimen. The methods to be employed are discussed in the following paragraphs:

Insertion of Plate—The photographic plate is enclosed in a cassette which is light tight to enable the instrument loading to be accomplished in a lighted laboratory. The door to the photographic chamber is located on the right-hand side of the instrument directly below the table top. The cassette snaps into a carriage which runs in grooves in the walls of the photographic chamber. The door can be closed and locked by rotating the handle on the door clockwise into place. The instrument can then be pumped down for operation.

Motion of Plate—Motion is imparted to the plate by a shaft passing through a rubber gasket into the photographic chamber. The cassette control knob, which is located on the vertical part of the control panel, is calibrated to indicate the position of the plate. The control knob should be in the "load" position when the cassette is inserted into the photographic chamber. To place the plate for the first exposure, the control should be turned four and a half turns counterclockwise to the "A" position. Releasing the shutter will then expose the end of the plate nearest the door to the photographic chamber. To make the other exposures the control is turned clockwise nearly one turn until it snaps into place at the desired position. It should be returned to "load" before removing the cassette. The control should be lubricated frequently by filling the oil well in the upper rear part of the knob with the prescribed mixture of octoil and graphite.

Exposure of Plate—To make the exposure the viewing screen is lifted by means of the camera cable release on the control panel. The flexible cable makes it possible for the operator to expose the plate without actually coming in contact with the instrument, and thereby vibrating the microscope column. For a micrograph, an exposure from one to fifteen seconds is usually used, depending on the intensity of illumination. For making these exposures turn the circular piece on the side of the cable release so that it slides under the small button. This arrangement simulates "snapshot" action. Diffraction patterns are usually photographed with an exposure from 30 to 60 seconds. The circular piece on the cable release should be turned so that the notch on the edge is directly under the button. This arrangement provides "timed" exposure conditions and relieves the operator from holding the cable release for long periods of time. The sliding doors on either side of the viewing chamber are closed during exposures to keep the light in the room from fogging the plate.

Removal of Plate—Before removing the plate, the high voltage and gun filament are turned off and air let into the column. The lock on the door to the photographic chamber is lifted and the door opened. The carriage which holds the cassette is permanently mounted in the photographic chamber. The cassette release should be lifted and pulled toward the operator. The cassette can be withdrawn and taken to a dark room to be unloaded and developed.

STEREO-MICROGRAPHS

Stereo-micrographs may be obtained through use of a special specimen holder (Stock #48404). When employed as described below, this holder will produce micrographs having a magnification nearly as great as that obtained with the standard specimen holder (Stock #48390).

In optical light microscopy, information regarding the three-dimensional structure of materials may be obtained by one of at least three methods, namely: series sections, optical sectioning, and stereo-photomicrography. The nature of the electron microscope specimens and the enormous depth of focus obtained in electron microscope images prevent the electron microscopist from using the first two of these methods. By employing the third method the electron microscope can be readily adapted to produce stereo pictures and give accurate information concerning the third dimensions of specimens. The actual experimental procedure, which is essentially the same as that used in obtaining stereo-pictures with the light microscope, produces micrographs of the same field from slightly different angles. To obtain stereo-micrographs in the electron microscope, a specially constructed specimen holder, provided with a mechanism for adjusting the angle between the axis of the microscope and the normal to the plane of the specimen, is used. Two micrographs of the desired field are made for which the above mentioned angle has equal but opposite values.

When shifting the stereo-holder it is advisable to turn the knob slowly, at the same time watching the image on the intermediate viewing screen. When the specimen holder snaps into position, the image jumps slightly. In this way the operator can identify the exact positions. Remember that the image will also jump in passing the central position. In order to stop the specimen holder at the central position it is necessary to turn the handle slightly past it and then back up. Watch the image closely and move the stage to compensate for any movement of the image on the screen. It is also advisable to adjust the first image on the final viewing screen so that some easily identified point is on the intersection at the center of the screen and be careful that it is on the same point when the second picture is taken.

In order to allow room for tilting the stereo-specimen holder, the specimen screen must be placed somewhat higher above the objective pole piece than with the standard holder. Then adjust the first image on the final viewing screen so that some easily identified point is on the intersection at the center of the screen and remains at that point when the second picture is taken. Where the actual depth of the material is relatively large, better visual concepts are obtained by reducing the angle of tilt. Obtain a stereo pair made from one tilted view and one with the holder in the mid-position, a total angle of 4°. The only differences in the two micrographs are the slight difference in magnification caused by the slight change in the distance between the specimen point and the objective, and those differences due to the fact that the plane has been tilted through an angle. The former effect is practically negligible. It can be kept to a minimum by restricting the stereo images to areas near the center of the specimen screen. The latter effect, differences in aspect due to tilting, accounts for the stereoscopic or three-dimensional appearance of the specimen when the finished prints are properly viewed.

In order to obtain the proper results, it is essential that the prints used for stereoscopic viewing be suitably prepared and oriented. Proper orientation of the prints is **particularly** important due to the fact that magnetic lenses cause an arbitrary amount of rotation of the image. It is therefore necessary to rotate the prints about corresponding points until all the displacements in the image that are due to the tilting of the specimen are parallel to the line joining the eyes of the observer. A simple way to accomplish this result is to take the stereoscopic pair of prints and superimpose them in front of a bright light so that both images can be seen. Some point in the field

is selected as the point that should appear nearest the observer, and the two images of that point are made to coincide. It will then be seen that the images of other corresponding points of the field of view do not exactly coincide, but are displaced slightly relative to one another in arbitrary directions. If the proper foreground point has been selected and the displacements are due to the stereoscopic effect only, the other parts can be made all parallel by rotating one picture over the other until the required condition obtains. The angular position of each print should then be accurately noted and maintained when the prints are permanently mounted for stereoscopic viewing.

A few remarks should be made in regard to the obtaining of successful stereo-micrographs. Specimens which show sign of moving or changing of their own accord while in the electron beam or otherwise, do not in general give true or even good stereo-micrographs. By shortening the time of observation of the specimen between exposures, changes in dimension of parts of the specimen, caused by metal sputtered from the wire screen support, will be reduced to a minimum. This is particularly true of specimens mounted without supporting membrane.

The rules for ordinary stereoscopic photography should be followed in making up prints, attention being paid to those details which can produce confusing effects, such as the position and shape of the borders.

It should also be pointed out that stereo-micrographs obtained in this way produce a dissociation of perspective and three-dimensional parallax phenomena. This is due to the fact that the perspective in the images corresponds to that which would be seen in an object situated in the neighborhood of 100 meters from the eye while the three-dimensional parallax effect corresponds (for an angle of 8°) to that which would be seen in an object at a distance of about 50 centimeters.

CALIBRATION OF THE MAGNIFICATION

(a) First Calibration Method

Generally speaking, calibration of the magnification is measured by comparison of photo-micrographs of a test specimen taken with the Electron Microscope and with a high-powered calibrated light microscope. For this procedure, the specimen is mounted in a standard specimen holder such as described before. A fairly large specimen is chosen; i. e., one which appears in about 3 or 4 openings of the specimen screen (about 150 microns x 150 microns), and which shows a number of readily distinguishable irregularities on its boundaries. The burrs formed by puncturing a specimen screen will make a convenient and rugged calibration specimen. A portion of this specimen is photographed at various settings of the projector control and with the different projector pole piece arrangements. A micrograph is now taken of the whole specimen in a calibrated light microscope and the magnification is computed for the several magnification ranges of the instrument. The light micrograph is used to calibrate the intermediate or low magnification series and the intermediate series is used to calibrate the high magnification steps. Obviously, the use of a larger specimen for the calibrated light micrographs should reduce the error of observed measurements by a large percentage.

(b) Alternate Calibration Method

An alternate method of calibration of the magnification involves the same photographic procedure as described above, but instead of measuring the specimen with a light microscope, a collodion replica is made of a diffraction grating having about 30,000 lines/inch. This replica of known line spacing can be photographed with the electron microscope at a projector setting which permits about a dozen lines to be included in the field and serves as a direct calibration of this projector setting. The replica may be saved and used to recalibrate the microscope at any time.

One precaution must be observed in using this method. The grating replica undergoes some distortion in stripping, and the line spacing should be determined by measuring the replica with a light microscope using a high-power dry objective. Since magnification depends on the current in the objective and projector coils as well as on the electron accelerating voltage, meter readings and control knob settings must be recorded with care for all calibration points. In addition, these readings must be watched for repetitive constancy, once calibration has been made. Presuming that the microscope has been calibrated at fixed values of objective current and accelerating voltage; in a given specimen plane; at various values of projector current control steps, there are certain factors which will affect repetitive accuracy. These are listed below:

1. Line voltage changes—(corrected by line regulating transformer).

2. Inconstancy of specimen plane, caused by variations of specimen height in supporting media; variations in supporting media; mechanical inaccuracies of exact replacement of specimen in calibrated plane.

3. Aberrations—dimensional changes as a result of distortion. These can be reduced to a minimum order, if measurements are confined to the central area of the electron cone.

4. Lens current or accelerating voltage changes (overcome by correcting electronic circuits—tubes, dry battery standards, or component parts).

5. Foreign particles in lens pole pieces (corrected by keeping inner configurations of pole pieces, surfaces of apertures and all points near to the electron beam free of dirt or particles subject to electrostatic charge).

6. Lens hysteresis effects.

These effects are compensated for as follows: The projector and objective current controls should be operated in one direction only (preferably clockwise) when calibrating or making succeeding measurements. Otherwise, hysteresis effects in the iron cores of the deflecting coils will affect the calibration accuracy. If a large change in current direction is required, it is best practice to reduce the affected circuit current to a minimum and advance slowly to the desired value.

It is safe to assume that, if necessary precautions are taken and careful measurements made, the error of magnification computations will not exceed 5 per cent.

(c) Direct Measurements of Magnification

A quick estimate of the size of a particle or part of a specimen may be obtained by noting that one revolution of the stage movement knob moves the specimen 0.001". The fluorescent screen is ruled in one inch squares. The image may be moved one inch, as measured on the screen, and the corresponding motion of the control knob observed. This distance (0.001" per revolution) is the distance the specimen has moved, and the magnification may be calculated immediately.

NORMAL METER READINGS

Normal meter readings are as follows:

Meter	Actual I or E
Condenser	10-25
Objective	3-80
Projector	150
Filament	0-60
Osc. I	130-150
Osc. E	600-900
Regulator	370

MAINTENANCE

Familiarity with the methods employed in routine care and servicing is essential in maintaining the proper functioning of the microscope. Therefore, the following discussion on "MAINTENANCE" should be carefully read and consulted as an adjunct in the periodic check-ups of the instrument. To obtain the ultimate in micrograph results, it is essential that every electrical and mechanical component of the Electron Microscope—from electron gun to photographic plate—be in good condition and in proper alignment.

WARNING: Voltages used in many of the circuits of the electron microscope are dangerous to life. Circuit checking and trouble shooting should be accomplished by no less than two operators. Even though power has been turned off, certain capacitors in the circuits are capable of storing electrical energy for considerable periods of time at voltages which are dangerous to life. Before touching any of these circuits, they should be grounded and discharged with a "grounding rod." The grounding rod must have a well-insulated handle. It must be grounded through a circuit which must be continuous and of low resistance. The grounding connector must be flexible to withstand usage. It should be exposed so that its continuity may be checked readily. In addition to grounding, it is accepted and good practice to test every circuit requiring examination with a voltmeter, before physical contact is made.

NOTE—As a general rule do not remove tubes from circuits which are in operation.

The following items should be checked regularly as a preventive measure:

a. The oil in the mechanical pump should be drained, the pump flushed with oil, and refilled every three months.

b. The diffusion pump should be drained, cleaned, and refilled every six months.

The vacuum system should be tested for leaks before inserting the oil in the diffusion pump. About 200 grams of the oil will be required. The fluid may be inserted from the top of the casing, or if the pump is already secured to the rest of the system, the oil may be sucked in through the drain tube at the bottom of the casing by applying the fore pump for a short interval and then screwing the metal cap in place while the inrushing air keeps the oil from flowing out again. When the pressure of the cap gradually causes the lead seat in the cap to lose its shape, the lead should be hammered or melted back into place with a blow-torch.

When the fluid in the pump must be removed the pump should be kept in an upright position until the volatile liquids which have been caught in the water-cooled trap on the side arm have been removed through the drain tube on this trap. The main body of the pump fluid can then be removed without danger of contamination from the material caught in the trap and should be preserved in a brown glass-stoppered bottle for future use. To avoid decomposition of the pump fluid, before exposing the pump to pressure above 1 mm. of mercury, allow the pump to cool to the point at which the vapors cease to be evolved from the boiler in large quantities. A ten to fifteen minute cooling period should be sufficient.

Used oil should be removed by rinsing the casing three or four times with acetone. With the caps removed from the two drain tubes, the acetone residue should then be removed completely by a blast of warm air.

c. The gears of the valve block, indicator dial, and stage movement should be lubricated with Lubrico grease, at intervals of from six months to a year.

d. The oil-impregnated rubber bushings which make the vacuum seals where motion must be transmitted into the microscope column should be lubricated every month. The recommended lubricant is a mixture of ten to twenty parts octoil to one of graphite, thoroughly emulsified. The

oilers to be filled are located in the following places:

1. Camera cassette control knob.
2. Camera cassette movement gears.
3. Diffraction stage.
4. Stereo door.

5 and 6. Specimen stage movement.

e. All wire around controls on the control panel should be cleaned periodically, using solvent and crocus paper.

The following items should be taken care of, if the operation of the instrument indicates that it is necessary:

a. The gun filament must be replaced in case it burns out or when it has been used so long that a high beam current is obtained when the filament current is low, and the intensity is hard to control.

b. If the image jumps and drifts about it is an indication of dirt in the column. The pole pieces should be cleaned. If the image continues to jump there may be dirt in the specimen holder, the condenser aperture may need cleaning, or the objective aperture may have to be replaced.

c. If a gradual loss in resolution is observed, it is probably an indication of an accumulation of dirt around one of the apertures.

d. The fluorescent material on the viewing screens must be replaced if it is damaged.

e. It may be necessary to clean the ionization gauge occasionally. This is done with hot caustic soda. THE MAIN POWER AND THE PANEL LIGHTS SHOULD BE TURNED OFF BEFORE HANDLING THE GAUGE. Access to the gauge can be had when the table top is removed. The gauge is held to the column by four Allen head screws, and the electrical connections are made by two insulated cap leads.

FILTER DRIER

The air which is let into the column is dried and cleaned by passing it through the air filter which is located in the right-hand side of the microscope cabinet. The cleaning is accomplished by the felt pads at the end of the filter. About once a year these should be cleaned thoroughly with a blast of air or replaced. The air is dried with "Indicating Drierite" or anhydrous calcium sulfate. The dehydrated Drierite is blue; as it absorbs water it becomes rose colored. When the Drierite becomes rose colored up to the "change line," it should be replaced by dry Drierite or the pump down time of the microscope will increase because the Drierite is saturated with water vapor which can be drawn into the column. The Drierite can be regenerated by heating in an open pan, in an oven or on a hot plate, at a temperature of from 200°C to 250°C (572°F). The Drierite should be agitated during the heating process because the water is released from the upper surface.

ROUTINE CARE

In order to obtain the best performance of the electron microscope, a certain amount of routine care is necessary. A preliminary check of the instrument should be made. In the course of routine inspection, the following items should be checked as suggested:

a. The most important factor is cleanliness. The microscope column, chassis and rotary pumps should be dusted. Foreign matter in the column may prevent the pumps from attaining the proper pressure, or produce image distortion due to electrostatic charges. Dust will contaminate the specimens, and cause defects in the photographic plates. The high voltage unit must be clean in order to prevent arcing or brush discharge.

b. Test all tubes periodically and replace those in which the mutual conductance value falls below 70 per cent of the initial value. The tube tester used should reveal operating characteristics such as mutual conductance, amplification factor, etc.

c. All "B" batteries (45 volts) should be tested at least once a week and any one should be replaced when its voltage falls below 42 volts. The total nominal voltage of the series of batteries located in the battery box on the left door is 382½ volts. Caution should be exercised in testing these batteries to avoid being shocked.

d. The test meter should be checked by adjusting the range switch to its various positions and comparing the results obtained with the normal meter readings tabulated at the end of the section on "Operation."

e. The corona shields and high voltage parts should be kept highly polished at all times.

SERVICING

The following section is given to a discussion on (a) care of rotary pump, (b) checking for vacuum leaks, (c) replacement of gun filament, (d) cleaning of pole pieces, (e) cleaning of apertures.

CARE OF THE PUMP

When the mechanical pump is turned on, check to see that the oil level is correct and that no oil has backed up into the pump line as far as the stop-cock. Detailed directions for the care of the pump are given on the name plate on the pump.

The motor should be lubricated regularly in accordance with the Cenco instructions for the pump. The pump should be operated with recommended Cenco Hyvac light grade vacuum pump oil. The oil level should be kept mid-way between the two lines of the oil level indicator. It is best to check the oil level while the pump is running.

CHECKING FOR VACUUM LEAKS

The following procedure is given to facilitate the location of leaks. A diagram of the entire vacuum system (M-427490) including pumps, valves, and gauges, as well as the implied functions of each is shown in Figure 6B. The technique of leak hunting and trouble shooting can be made much easier and much labor can be avoided if this vacuum system diagram is kept in mind and used as a step-by-step guide for trouble isolation.

If the microscope should fail to pump down to the operating pressure in about 15 minutes (after a 12-hour stand) time, the following points should be checked before beginning a systematic search of the microscope column.

a. Be sure that both the fore pump and the diffusion pump are operating.

b. If the proper fore pressure cannot be obtained with the valve block in "load," the trouble must be with the fore pump or a leak in the fore line, valve block, or diffusion pump.

c. Any joints which can be mechanically disturbed, such as the fore line, cassette control and stage movement controls should be checked to see if movement changes the pressure reading.

d. All joints which are held by screws should be checked to see if tightening the screws changes the pressure reading.

e. All seals which are made by oil impregnated rubber bushings should be lubricated with octoil and graphite to see if any change is made.

When it is fairly certain that a small leak is confined to a known section of the microscope, castor oil can be applied sparingly to the various parts of the isolated section until the leak is discovered, at which time the gauges will indicate a decrease in internal pressure. A common and practical method of testing for small leaks involves the use of a 4-oz. atomizer filled with ether. All joints and surfaces are sprayed until there is an indication that the internal pressure has increased. Ether, having a high vapor pressure, seeps readily through the perforation fault, and gives an immediate indication of increased pressure. Hydrogen gas is as effective as ether, but not generally as easily available and involves explosion hazards unless severe caution is exercised. Acetone is also an effective substitute for ether, but unfortunately it is a solvent for the baked-on finish of the microscope. Large leaks, generally, must be found by dismantling the microscope column section by section. As each section is removed, the exposed openings of the remaining part of the column must be temporarily sealed and the vacuum test continued. Temporary seals can be made from thin pieces of neoprene or sulfur-free rubber sheets held in place over the exposed openings by the weight of suitable metal plates. After isolation, the perforation fault of an offending section can be readily found by one of two methods. In the first method, the section is sealed off by means of clamps, gaskets, and gasket plates, with the exception of an orifice where air pressure (2 or 3 pounds) can be introduced. The bubble stream appearing when the section is submerged in alcohol, with the air pressure applied, gives an immediate clue to the source of the leak. Alcohol is used because of its low surface tension and freedom from trapped gases in the form of bubbles. In the second method, the same procedure is used except that, instead of alcohol immersion, the section is painted with soap bubbles. The source of the leak, of course, is the point at which new bubbles are constantly appearing within the lather.

In dismantling and reassembling the microscope vacuum system, the following precautions are very important:

a. Diligently label all screws, washers, gaskets, etc., so they can be returned to their original positions.

b. Be careful not to damage or mar gasket seats. Any damage may result in leaks.

c. Do not expose the microscope interior or inner parts to atmosphere and particularly to dust for any longer period of time than absolutely necessary. Dust particles, lint, etc., can pick up electrostatic charges from the electron beam and seriously interfere with the quality of the final image. This is particularly true of dust particles which settle on the apertures or inner configuration of the pole pieces. Electrostatically charged foreign particles can cause the final image to move continually or to oscillate. These phenomena, however, are distinct from image drift caused by electrostatic charges taken up by certain types of specimens, and for which, at present writing, there is no certain cure.

When the microscope is reassembled after some parts have been subjected to water, alcohol, or other substances, it will be found that the pump-down time to remove gases may be an hour or longer. However, from this point on, provided that the system is tight and no further contamination other than routine is permitted, pump-down time will shortly reduce to a point where, with a hot diffusion pump, not more than 1 to 3 minutes will be required to reach operating pressure from a standing-still sealed-off period of 12 hours.

GASKETS

Since the column of the microscope must be evacuated before the instrument can be put into operation, it is necessary for all joints to be vacuum tight. The following points should be observed in the preparation of gaskets and assembly of the column:

a. Gaskets can be cut by using a compass, a phonograph needle on a flying arm attached to a drill press, or a sharp knife. Water is a satisfactory lubricant.

b. All gaskets should be inspected for defects, such as holes in the edge, soft spots and irregularities in thickness. These can sometimes be detected by stretching the gasket. If necessary, the flat surface should be ground on a #200 abrasive paper. A gasket can be checked for flatness by putting a small amount of Celloseal on it, pressing between two glass plates and observing to see if it makes contact all the way around.

c. All gasket seats should be carefully polished with a #200 abrasive followed by crocus cloth, to remove radial scratches. Very small scratches

are especially to be avoided, since the rubber, although under pressure, cannot seal scratches. The gasket seats should be perfectly clean in order to insure a tight seal.

d. To cement a gasket in place, use Reanite 111K or Cycleweld cement. The gasket should be clamped in place and vulcanized in an oven for about half an hour.

e. Where motion is to be transmitted into the vacuum chamber, the seal is made by a rubber bushing surrounding the shaft and impregnated with octoil and graphite. The recommended mixture is about ten to twenty parts of octoil to one of graphite, thoroughly emulsified.

f. Gaskets which are not cemented in place should have a small amount of Celloseal rubbed onto the surface. This softens the gasket material and acts as a cement.

g. When the column is assembled it should be checked after each unit is added, by blocking off that unit with a gasket and flat plate and checking to see if it will pump down. Considerable time will be saved in locating the trouble if there should be a faulty gasket or some other leak.

REPLACEMENT OF COATING ON FLUORESCENT VIEWING SCREENS

Fluorescent material, ZnS-CdS-2272 (1-oz. bottle Stock No. 47656) is available for coating screens used in the electron microscope. The material has a brilliant yellow fluorescence, is light yellow when viewed by daylight, has a finer particle size than the standard Willemite formerly used and produces three times the visible light given off by Willemite under the same electron bombardment. The color excited is in the region of greatest sensitivity of the eye.

Preparation—ZnS-CdS-2272 comes in the form of a fine powder which must be suspended in a volatile solvent for coating. It is recommended that 1 oz. of the material be suspended in 8 ozs. of acetone. This mixture must be stirred well in order to break up agglomerates of the fine particles. It may then be stored and used as necessary. The inclusion of a small amount of 2% parlodion solution (2% parlodion in amyl acetate as commonly used for specimen supporting films) tends to make the phosphor adhere more securely to the metal.

Application—The simplest method of coating the surfaces is to use a spray gun. A kit that has been found satisfactory consists of the following parts obtainable from the DeVilbiss Company, Toledo, Ohio:

1 type CH-502 Spray Gun with type C-625 Cap.
1 #90 Air Cap.
1 #902 Air Cap.
1 type H Fluid Cap.
1 type F Fluid Cap.
1 Connection H-601.
10 feet tubing type H1080.
2 C-625 Cups (6-oz, glass).
1 type C Suction Cup Feed Attachment.

These components permit a wide range of spray control, and the best combination for use can be found by experiment.

It is essential that the compressed air used to operate the spray gun be free of oil, water, and dust, as contamination of the fluorescent material seriously affects its performance. A Cenco Oil Separator and Air Filter #1395M or equivalent should give good results when inserted in the air line.

The best distance at which to hold the gun when spraying a surface is determined by the air pressure used and the rate of evaporation of the solvent. If the gun is held too close to the surface, droplets will form and a non-uniform coating will result. On the other hand, if the gun is too far away the solvent will evaporate too soon and the coating will not stick. A little practice will permit the correct technique to be determined.

If a finer, more uniform coating than can be obtained by spraying is desired, the surface may be covered by allowing the fluorescent material to settle on to the screen. For this process, the screen should be placed in an evaporating dish which is equipped with a stop-cock in the bottom. The well-dispersed suspension is then poured in, the dish covered, and the stop-cock opened so that the liquid may drip out slowly. A very uniform coating of small particles and concomitant high resolving power may be obtained in this manner. Such a coating is required only for the final viewing screen, however, as high resolution is not essential for the intermediate or gun screens.

As thin a layer of ZnS-CdS-2272 as practicable should be used on the gun and intermediate screens. The metal should still be visible through the coating. If too much of the phosphor is used, serious optical difficulties will arise because of the considerable electrostatic charge built up by the material. The final viewing screen should have a heavier coating, as it must be adequately covered in order to provide sufficient intensity and detail. However, an adequate coating is one which is just sufficient to completely cover the metal surface. Too heavy a coating may result in image distortion.

Alternate Procedure—Thoroughly clean and dry the metal plate on which the fluorescent material is to be applied. Place two grams of phosphor (either ZnS-CdS-2272 or 33Z605B which may be obtained from RCA Victor Division, Radio Corporation of America, Camden, New Jersey) in the smallest possible container. Make a binder solution of 1 cc J26AR nitrocellulose solution* plus 3 cc of clean amyl acetate. Add

*J26AR is a solution of nitrocellulose in toluene and butyl acetate, containing about 11% nitrocellulose by weight. It is obtainable from U. S. Industrial Chemicals, Inc., New York, N. Y. If desired, a 10% solution of nitrocellulose in amyl acetate may be substituted for J26AR.

Do NOT use an ether solution of collodion; the ether evaporates much too rapidly.

the binder solution to the phosphor and, with a clean glass rod, thoroughly mix the two until a uniform suspension is obtained. Quickly pour this suspension onto the metal plate spreading it around until the plate is uniformly covered. The plate may be tilted slightly to aid the spreading of the mixture. Care should be taken to see that none of the suspension drips over the edge of the plate. Set the plate in a dust free area with good ventilation and allow it to dry at room temperature. During the first part of the drying process, it is advisable to cover the screen to reduce the speed of evaporation of the solvent. During this time many bubbles in the mixture will rise to the top and break. When no bubbles remain, the cover should be removed and drying may proceed more rapidly.

The resulting screen should be uniformly coated and the thickness should be such that the metal plate is well covered.

Care should be taken to avoid having an intense concentrated beam strike the plate for an extended period, as slight charring of the nitrocellulose binder may occur at the point of bombardment resulting in the formation of a brown spot.

If the screen becomes soiled, it may be cleaned by gently rubbing it with 4/0 emery paper to remove the top surface and blowing the dust off with clean, dry air. Should the screen become too thin or lose intensity for any reason, and if it cannot be brightened by removing the top layer, the phosphor should be completely removed and the plate recoated.

SOLDERING PROCEDURE

The following soldering procedure is particularly applicable to the repair and installation of bellows.

a. All surfaces requiring tinning must first be cleaned. Fine sandpaper and a solvent may be required.

b. Use zinc chloride as a flux. Do not permit any other flux to come in contact with the work. Keep soldering iron free from any other type of flux.

c. Immediately after tinning operation, thoroughly remove all traces of flux with hot running water.

d. Tinned surfaces which are to be joined to each other, should not be left unassembled for more than 24 hours.

e. When bellows attached to parts having large heat capacity must be replaced, heat the entire assembly on a hot plate until the old solder melts. The damaged bellows can then be removed easily and the new one installed. While the parts are still hot, a soldering iron should be used to smooth the seal and make a vacuum tight joint.

f. Wherever possible, avoid using flux when assembling or joining parts with tinned surfaces.

g. Where flux may be required in Item f, resin is recommended as the flux. All traces of resin should be removed with alcohol after soldering operations. Paint any new bellows with a thin coat of glyptal lacquer (General Electric #1202 glyptal and #1500 thinner) after it has been soldered and before installing it in the microscope, inhibiting corrosion and sealing any pinholes in the body of the sylphon or soldered joints.

REPLACEMENT OF THE ELECTRON GUN FILAMENT

In order to obtain sufficient emission for an adequately bright final image, it is necessary to run the electron microscope filament at a temperature which is considerably higher than that used in ordinary electronic tubes. As a result of this higher operating temperature and the relatively poor vacuum used in the microscope, the filament deteriorates rather rapidly. In operation, this deterioration becomes apparent by a change in the operating position of the filament control. As the filament becomes thinner, less heating current is required to heat it to the temperature at which the total beam current is 450 microamperes. As the filament is used, the position of the knob marked "FILAMENT," at which a total beam current as read on the "BEAM" meter registers 450 microamperes, will gradually recede to the left. Finally, it will be found that when the "FILAMENT" knob is turned counterclockwise as far as possible the beam current on the "BEAM" meter will be about 500 microamperes, and eventually will be sufficient to overload the high tension system and actuate the protective relay and "OVERLOAD" lamp. When this point is reached, the filament must be replaced. The procedure for replacing the electron gun filament is as follows:

The first step is to turn off filament, high voltage, and main power. Then, in order to gain access to the electron gun, the hood which covers the gun is pushed up until the supporting bracket locks into position. At the same time, the high voltage bushing is automatically grounded. To remove the filament assembly it is first necessary to disconnect the three leads passing through the tube from the bushing through the corona shield. The two leads with spade tips are freed by loosening the screw which clamps them, and the third lead to the center terminal of the gun is merely lifted off. Next the corona ring on top of the gun should be removed.

The valve control handle should then be turned until the valve block is in the "LOADING" position so that air is admitted to the column. The four screws on top of the electron gun are then removed and the filament assembly is lifted out, care being taken not to scratch the shield on adjacent parts.

The shield is now removed by unscrewing it and carefully sliding it off over the bellows and filament supporting block, thus exposing the filament. The two small Allen setscrews in the filament supporting block should then be loosened and the filament assembly, including the mica disc, is lifted out. This assembly should be saved, as new filaments can be spot-welded on to it. A new filament assembly is then placed on the block and clamped into position by tightening the Allen setscrews. The shield is now carefully slipped back over the filament and screwed into position. The tip of the filament should now be quite accurately at the center of the aperture in the shield. If this condition is not met, the aperture end of the shield should be unscrewed and the filament bent gently with a pair of forceps, until the tip is centered with respect to the aperture. The entire shield should now be wiped with a soft cloth or chamois which has been wet with alcohol, in order to remove any fingerprints, lint, or dust. By turning the worm gear at the top of the filament assembly, the height of the filament should be adjusted until the tip of the filament is nearly in the plane of the aperture, at which point the filament will be too low and, when the beam is turned on, the easily recognizable astroid pattern will be obtained on the gun screen. One precaution must be noted: In setting the filament too low be sure that the filament itself does not touch the shield, or it will cause a short circuit.

The entire filament assembly should now be reinstalled in the microscope, the steps being the same as those described for removing the filament, but followed in the reverse order. With the microscope pumped down and the beam turned on, the filament height should be adjusted as described in the section under "ALIGNMENT."

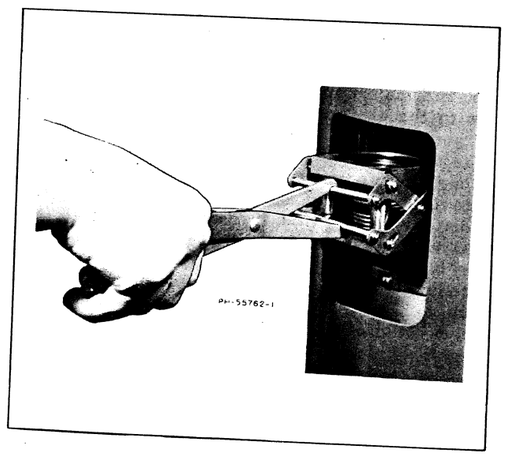


Figure 15—Installation or Removal of Bellows in Intermediate Tube

CLEANING POLE PIECES

a. Before attempting to remove the bellows and pole pieces, turn the crank handle on the right side of the microscope until the dial indicates "loading" position. Admit air into the column to reduce the pressure.

b. Slide back the cover over the opening to the objective chamber.

c. With the forceps provided for the purpose, grip the bellows and remove it.

d. With a spanner wrench, loosen the screw supporting the objective pole piece.

e. Lift out the projector viewing screen.

The objective and projector pole pieces require routine inspection and must be carefully cleaned to remove all traces of foreign material. Preliminary cleaning can be accomplished with a rinse in acetone or carbon tetrachloride and should be followed by hand drying with a clean chamois. A toothpick, or better still, a piece of orange wood can be used as a reamer to ream clean the sides of the hole. After this cleaning, the pole piece hole should be examined carefully with at least a 5x eyepiece. Particles still adhering can be removed with fine tweezers or the orange stick. Compressed air cleaning is not recommended because of the dirt particles inherent in the blast. After cleaning, the pole pieces should be protected from dust if they are not to be used in the microscope column immediately.

The prime cause of image movement in micrographs is dirt or lint in the confines of the pole pieces, apertures, specimen holder, etc. Too much care cannot be given in insuring cleanliness in these accessories. Fixed images also depend on column alignment. A properly aligned column produces image rotation only, as lens currents are varied. Changing the beam current in an aligned column having constant accelerating and lens voltage is equivalent to changing the quantity of illumination and should not produce image movement unless there is dirt in the system.

Any foreign material in the confines of the optical system will assume electrostatic charges from the electron beam. If the foreign material is in the form of an insulating or semi-insulating particle or film, the charge accumulation will raise the potential of its surface. The field produced between this charged surface and the microscope column will deflect and distort the electron beam. If the foreign material is a good insulator its surface may charge to such a potential that the insulation breaks down suddenly and the charge disappears. At the same time, the potential between the surface of the material and the microscope column also disappears. Immediately, the surface of the foreign material will begin to charge again. This results in a periodic deflection of the image, characterized by a slow drift in one direction followed by a quick restoration to the original position. If the conductance of

the foreign material is sufficient to prevent the surface reaching the breakdown potential, a steady state may be reached, for which the surface of the particle reaches a steady potential and the image is permanently deflected and distorted by a constant amount. Under these conditions, however, the potential of the surface and hence, the amount of deflection of the beam, depend on the number of electrons striking the particle, i. e., on the intensity of the beam. Thus, if the beam intensity changes for any reason, the image will move accordingly and result in unusable micrographs. Likewise, the lens aberrations caused by these spurious fields are sufficient to render micrographs inferior even though the spurious field potentials tend to remain fixed and constant.

The above-described image movements and their causes are not to be confused with random image movement caused by possible changes in the electrostatic charges accumulated in the specimen itself. These effects depend on the type of material and its disposition and dispersion on the supporting film and screen. However, image movement of this type is quite often continuous in a given direction. Charges then accumulate on the particles of the specimen and as a result of their mutual repulsion, cause film rupture and movement. In rare cases, materials such as animal fur and various types of cellulose have exhibited oscillatory motion. The cure for these cases and others involving the specimen itself must be found by experiment, and at this writing, there are many materials still lacking satisfactory "quieting" techniques.

To replace bellows and pole pieces, reverse the order in which they are removed.

APERTURES

If an objective aperture is used, it should be as close to 0.001″ diameter as possible. An objective aperture will enhance resolution and contrast for some types of specimens.

Electron optical components of the column (including apertures) not covered in the above instructions can be cleaned by employing solvent, chamois, orange stick and distilled water as best suits each condition. Parts which are coated with fluorescent materials should be carefully handled to avoid damage. The edges of the holes of the primary intermediate screens should be freed of fluorescent material inasmuch as this material is highly electrostatic. The pointed end of a toothpick will remove fluorescent material at the surface edge while the body and end of the toothpick can be used inside the hole.

REALIGNMENT OF MICROSCOPE

After having replaced the objective aperture, or after reassembling the microscope column, the entire microscope must be realigned. The systematic alignment procedure is described in the section on "Operation" in this book. The microscope should be realigned after standing idle for any great length of time.

CENTERING OF SPECIMEN STAGE

If the specimen stage should require centering, the procedure is as follows:

a. Insert the centering pin through the stage in the same manner as a specimen holder. Do not force it into the objective pole piece.

b. By manipulating the movement knobs on the control panel, adjust the stage until the centering pin drops into the objective pole piece beneath the stage, by its own weight.

c. If necessary, relocate the stops on the two external gears of the stage movement to mid-position.

d. Adjust torsion springs so that when the stop is rotated to its utmost counterclockwise position, the end of the spring is pulled to the first hole past the corner of the stop. If this torsion is not satisfactory over the entire range of the control knob, hook it into an adjacent hole.

The gears of the stage movement should be lubricated occasionally with Lubrico grease. (Intervals of six months to a year should be satisfactory.) The shafts which transmit the motion to the stage should be kept lubricated with octoil and graphite in order to maintain a vacuum seal.

OVERLOAD RELAY, ADJUSTMENT PROCEDURE

Caution—Adjustments 1, 2 and 3 below should not be necessary under normal conditions of usage and wear. Adjustment 4 may be necessary if contact pressures become unequal. Adjustment 5 sets the "pick-up" and "drop-out" currents and such adjustment may be necessary at time of installation. In general, adjustments should be made in order listed, if necessary. For example: If adjustment 2 is necessary, adjustments 3, 4 and 5 should be checked and readjusted, if necessary, after adjustment 2 is made.

1. Closed Air Gap Adjustment—With the relay armature in closed position, adjust the anti-freeze pin by inserting a .005″ feeler gauge between the relay armature and the edge of the pole face nearest the hinge while turning the pin clockwise to open the gap, or counterclockwise to close the gap until the gauge just clears. Then set the lock nut on the anti-freeze pin.

2. Open Air Gap Adjustment—With the relay armature in open position, adjust the armature limit pin by turning the pin clockwise to close the gap, or counterclockwise to open the gap until a .012″ feeler gauge between the pole face and anti-freeze pin will just clear. Then set the lock nut on limit pin.

3. Adjust the contact gap with the relay armature open by turning the normally closed contact pin clockwise to close the gap, or counterclockwise to open the gap until a .015″ feeler gauge between the contact armature and normally open contact will just clear. Set the lock nut on N. C. contact pin.

4. To obtain equal contact pressures on both the normally closed and normally open contacts, turn the contact pressure adjusting screw clockwise to decrease normally closed contact pressure and increase normally open contact pressure. Similarly, to increase normally closed contact pressure and decrease normally open contact pressure, turn the contact pressure adjusting screw counterclockwise. Set the locknut, taking care that the adjusting screw does not turn.

If the contact arm does not leave either the normally closed or normally open contacts when the relay armature is opened or closed, the approximate setting of the contact pressure adjusting screw may be determined as follows:

(a) Turn the contact pressure adjusting screw counterclockwise until the normally closed contact will not open when the relay armature is closed. Hold the relay armature closed and turn the contact pressure adjusting screw clockwise until the contact arm snaps into closed position. Mark the position of the adjusting screw.

(b) Continue turning the contact pressure adjusting screw clockwise until the contact arm remains in closed position whether the relay armature is open or closed. Then, with the relay armature open, turn the contact pressure adjusting screw counterclockwise until the contact arm snaps into open position. Mark this position of the adjusting screw.

The approximate setting of the contact pressure adjusting screw for equal contact pressures and equal wipe on each contact is midway between the two points (a) and (b) above.

5. Final adjustment of pick-up and drop-out current values is obtained by turning the elastic stop nut on the relay armature compression spring. To increase pick-up current and decrease drop-out current, turn the nut clockwise. Turning the nut counterclockwise decreases pick-up current and increases drop-out current.

6. The relay must operate on .70 to .75 ma. After operation, the relay must drop out on .20 to .30 ma.

7. The pressure between the contact arm and either contact must be 4+ grams.

ADJUSTMENT OF 50 KILOVOLT SUPPLY

The high voltage may be adjusted to 50 kilovolts by setting the total voltage from the bank of eight 45-volt batteries plus a 22½-volt tapped battery. These batteries, B-1 to B-9, are located in the battery box on the left-hand door of the cabinet. In steps of 1½ volts, the battery voltage may be varied from 382½ volts to 282½ volts. Voltages between 382½ and 360 volts are obtained by moving the connections on the tapped battery, B-9, in the top right corner of the battery box. The proper battery voltage is determined by the resistance of the high voltage feedback resistor, R-65, and is adjusted for each microscope before leaving the factory.

Three shorting plugs are provided with each instrument for use in the battery box when less than 360 volts are required. Two of the shorting plugs have all of their terminals connected together, the third plug has a pair of leads approximately 3 inches long.

When a battery box voltage between 360 volts and 337½ volts is required, the battery B-8, fourth from the bottom on the righ-hand side of the box, must be removed. The shorting plug having two leads must be inserted securely in its place, and the two leads from the plug must be connected to the two terminals of a 22½-volt battery (similar to B-11). The correct polarity must be observed, and may be obtained by connecting the red lead to the positive (+) terminal and the black lead to the negative (−) terminal of the battery. Variations in voltage within the range are obtained by adjusting taps on the 22½-volt tapped battery, B-9.

For voltages from 337½ volts to 315 volts, a shorting plug of the type having all its terminals connected together is inserted in the battery box in place of battery B-8.

In a similar manner, remove batteries B-7, etc., as may be required, to adjust the output voltage of the battery box to the lowest value necessary to deliver 50 kilovolts from the high voltage unit, when resistor R-65 may have a resistance at the upper tolerance limit. The relationship between the measured value of the resistor R-65 and the battery voltage required for 50 kilovolts output is shown in Figure 80.

The proper combination of batteries and shorting plugs is determined for each microscope in the factory. Any shorting plugs required are shipped in place in the battery box. Any shorting plugs not required at the time the instrument leaves the factory are shipped with the accessories to the microscope. Battery replacements should be made with the same combination of batteries and shorting plugs as those supplied with the instrument. It is recommended that complete battery replacement be made approximately every six months for optimum performance of the microscope.

A change in the output voltage of the battery box should be necessary only if the high voltage feedback resistor R-65, has been replaced.

TOUCH-UP ENAMEL KIT

Under this title is comprised a kit including the various paint finishes used on the electron microscope. The kit is made up of the following items:

1. One 1-pint can of enamel, Fin. No. 701 (light cobalt gray).

2. One 1-pint can of enamel, Fin. No. 702 (dark cobalt gray).

3. One 1-quart can of thinner, RCA No. 3.

4. One packing list.

Items 1 and 2 (Finishes Nos. 701 and 702) are applied on the microscope column and outer cabinet surfaces. Item 1 (Finish No. 701) is

employed on the interior of the cabinet and other inside parts. These finishes are used with one part of RCA No. 3 thinner for the first or prime coats. For second or touch-up coats, they may be used without a thinner.

The thinner is highly inflammable and should not be used near an open flame. Sufficient ventilation must be available at all times during its use. For best results, Finishes Nos. 701 and 702 may be sprayed in covering large areas. Small areas and marred surfaces can be touched up with a soft brush.

All outside finishes can be protected and improved through application of Simonize wax or equivalent.

METHODS FOR PREPARATION OF SUPPORTING MEMBRANE AND SPECIMEN ITSELF

Casting—In this method the materials from which the membrane is to be made is dissolved in a volatile solvent. A drop of this solution is placed on the surface of a suitable liquid. A satisfactory choice for this liquid is one in which neither the membrane material nor the solvent will dissolve, and which has a higher surface tension than the solution. When a drop of the solution is placed on the surface of the liquid the difference in surface tension allows the drop to spread over a considerable area. This exposes a large area to the air thus allowing the solvent to evaporate quickly, leaving a thin solid film on the surface of the liquid. This film may then be mounted by the method described below.

Dipping—This method is particularly applicable to the observation of the structure of the films themselves. Merely dip the screen specimen holder into a dilute solution of the material, remove it, and allow it to drain and to dry. After the concentration of the solution has been properly adjusted and the process carried out in a standardized manner, it is possible to produce, across the opening of the specimen holder, extremely thin films suitable for observation with the electron microscope.

Stripping—This method was first developed for electron diffraction work. A solution of the materials from which the membrane is to be made is coated on the surface of a specially cleansed piece of glass. Once again the solvent used must be volatile. Before the solvent evaporates, the thickness of the layer on the glass is made extremely uniform by spreading the solution by means of a special gauge. This gauge usually consists of a razor edge mounted so that when it is passed over the glass surface there is a constant spacing between the edge and the surface of the glass plate. This thickness is adjusted so that when the solvent evaporates, a solid film of the desired thickness will be left on the surface of the glass. A heavy frame of the material is then painted around the thin film area so that a fairly substantial edge is provided which helps in the stripping process. Loosen one side of the thick edge of the film and lower the glass plate obliquely into clean water, film side up.

If the glass and water surface have been properly cleansed, the film will float off onto the surface of the water. It may then be mounted by one of the methods described below.

In the following description of the various types of preparation technique, the method by which the preparation is mounted on the screen specimen mount will be mentioned. However, owing to the extreme importance of one of these methods, this one will be described in detail. This method will be referred to in the following as the mounting of a cast film. In particular, the type of film prepared will be collodion.

A well-filtered solution of collodion in amyl acetate (2% collodion) is drawn up into an eyedropper and a single drop placed carefully on the surface of well-distilled water. For the concentration of the solution mentioned above, the water surface should be at least 20 centimeters in diameter, preferably circular, while the drop size should be of the order of 1.5 millimeters in diameter. On reaching the water surface, the drop spreads over a fairly large area and the amyl acetate evaporates leaving the desired film of collodion floating on the surface of the water. During the process of spreading and evaporating, interference colors can be seen in the film and can be used as a check on the quality of the film to be obtained. Such interference colors should appear either uniform over the whole of the surface of the film or in fairly uniform broad circles. In the last stages of drying the thickness of the film is much less than the minimum which will give interference colors. However, when the drying is completed, the remaining film may be detected by a difference in the sheen of the water surface. Moreover, a good film appears to be surrounded by a very narrow corrugated edge. The edge of the film should, of course, be approximately circular if the spreading took place uniformly. By measuring the diameter of the film on the surface of the water, it is possible to calculate the thickness, if the size of the original drop and the concentration of solid material in that drop are known.

After a film has been obtained on the surface of the water, a number of screen discs are placed around the surface. These are picked up in the circular loop from below. In order to leave all of the film except the part being used undisturbed, a needle is run quickly around the edge of the loop, thus cutting out that portion of the film. As it is lifted out of the water, the wire loop carries the screen disc supported in its opening on the collodion membrane and a certain amount of water which still adheres to the lower side of the membrane and the loop. The screen disc is inverted and passed over one of the small cylinders. A pair of forceps is now used to lift the cylinder up through the loop so that the latter may be taken off the bottom. After this operation, the screen disc rests on top of the cylinder and is completely covered by the collodion mem-

brane, upon which there usually adhere a few drops of surplus water. The surplus water is then drawn off immediately by means of a micropipette. As water does not readily wet collodion, the extra drops of water drawn off in the manner described above, come off very completely and take all foreign material either in the water or on the surface of the drop with it. The specimen mount is then ready for the addition of the specimen, or, if the preparation is of the kind where the specimen is imbedded directly in the collodion itself, is ready for observation in the electron microscope. Films prepared in this way have been found to be extremely clean and do not possess any structure of their own.

Alternate Method for Screen Film Preparation—An alternate method for preparing the screen films is described below. This is simpler than the method set forth in the preceding paragraphs, and does not require any special tools to be used.

a. In the same manner as explained in the first column of this page, prepare a thin film of collodion on the surface of well distilled water contained in a vessel at least 20 centimeters in diameter. The vessel should be filled with water up to a level of about three to four inches.

b. Place 6 or 8 screen discs on the film surface along two parallel rows. The discs in each row as well as the two rows themselves should be about ¼ inch apart from each other.

c. With a clean tool, gently press down each disc so that the collodion film will adhere to the screen mesh of the discs.

d. Taking a very clean microscope slide, hold this vertically over the surface, with one of the small edges at the bottom, about ¼ inch from the end of the two rows of discs.

e. Then move the slide downward into the water. The collodion film on the water surface will thereby be pushed down, fold up around the bottom edge of the slide, and apply against the face of the slide, to which it will adhere. The screen discs, in this manner, find themselves between the face of the glass slide and the collodion film.

f. Pull the slide upward vertically out of the water, drain off the excess water by holding the bottom edge of the slide against a clean piece of cloth or blotting paper. Then allow the slide to dry about 5 minutes.

g. The collodion coated screen discs may now be removed from the slide and are ready for use.

Metal-Shadow Casting Method—Many materials of low contrast, such as replicas, bacteria, etc., may have their contrast enhanced by placing the collodion covered specimen screens in a vacuum chamber and evaporating a thin coat of heavy metal onto the preparation at a low angle. The coating should be sufficiently thin to permit its being penetrated by the electron beam, but the metal must have sufficiently high atomic weight

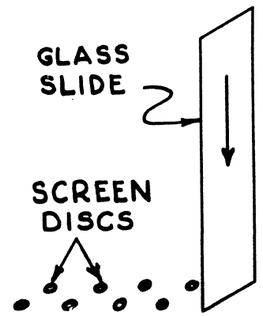


Figure 16—Screen Film Preparation
(*K*-885394)

to produce strong scattering. Information on the method of metal shadowing may be found in the following papers:

1. Williams, R. C. and Wyckoff, R. W. G.
Applications of Metallic Shadow-Casting to Microscopy
J. Applied Physics, 17, 23-33 (1946)

2. Williams, R. C. and Wyckoff, R. W. G.
Electron Shadow-Micrography of Virus Particles
Proceedings of Society for Experimental Biology and Medicine 58, 267-70 (1945)

For materials having detail of the order of 50 Angstrom units or less, gold has been found to be an extremely satisfactory shadowing material. A film of gold about 10 to 20 Angstrom units in thickness can be evaporated in vacuo from a hot filament placed about 3 cm. above and 15 cm. to one side of the specimens to be coated. The vacuum within the chamber must be better than 10^{-4} mm. of Hg, and pumping should be continued for about an hour after this vacuum has been attained in order to allow adsorbed gases to escape from the specimen itself before shadowing is started.

For the observation of larger structures, such as are found in replicas, a film of chromium about 50 to 70 Angstrom units thick has been found to be very satisfactory.

PROBLEMS ASSOCIATED WITH PREPARATION AND OBSERVATION OF ELECTRON MICROSCOPE SPECIMENS

There are a number of difficulties which must be overcome in order to obtain a successful electron micrograph of any particular material. The first of these includes those difficulties encountered in the actual preparation of the specimen. The second group includes those effects which result in the destruction of the supporting membrane of the specimen during observation. The third group includes the difficulties being encountered due

to the effects of the electron beam on the specimen itself.

In the preparation of a specimen for the electron microscope, one of the first difficulties encountered is that due to the presence of impurities. The instrument is capable of detecting such minute quantities of materials, that impurities which exist in concentrations of only one part in several million can easily be detected. In the case of specimens of approximately known characteristics, such impurities are not of any great importance since they may be easily recognized for what they are. On the other hand, if the investigation is to be carried out with materials of unknown properties, the impurities present must be either eliminated completely or identified in order that they may be recognized in subsequent work.

It is, of course, essential that the mounting membranes be absolutely free of any structure due to impurities in the materials used or to faults in the forming process. The most important difficulty to be found in the preparation of specimens from a liquid dispersion, is due to the surface tension of the liquids used. This effect is particularly annoying if the surface tension is such that the liquid does not wet the collodion, for, in this case, the liquid, upon drying, will gather in droplets around the larger particles of the specimen. It is exceedingly difficult to get an even distribution of the specimen material under such conditions. The difficulty can often be overcome by using one of the other methods of preparation.

Other phenomena which must be kept in mind in connection with this type of specimen, particularly when an aqueous suspension is used, are those due to changes in pH. with drying, changes in concentration with resulting changes in osmotic effects, and fractionation due to size selection by the method of preparation.

One of the most common effects encountered in the observation of specimens which contain some larger particles or groups of particles is the rupture of the supporting membrane due to electrostatic forces. Owing to the fact that the supporting membrane is an excellent insulator, any charges which appear on the surfaces of larger particles due to the absorption of beam electrons tend to build up until appreciable potentials are reached. Such particles will be repelled by neighboring particles with a force strong enough to rupture the supporting membrane. Successful micrographs can seldom be made of specimens that have been ruptured in this way because they seldom reach an equilibrium state which is independent of beam intensity.

A second effect that may cause a membrane to rupture is the heating of particles by the absorption of beam electrons to temperatures above the melting point of the material of which the film is made. As in the preceding case, this phenomenon occurs only in presence of large particles. A cure for both difficulties may be found by eliminating the larger particles from the specimen.

When it is necessary to obtain a micrograph of a specimen which consists mainly of larger particles, it is often possible to use a low intensity illuminating beam and photographic focusing.

The effect of the electron beam itself on the specimen may appear in the electron image in a number of ways. These include the effects which are due to heating of the specimen, decomposition due to heat and excitation from the electron beam, evaporation in the vacuum and under the excitation of the electron beam, and finally, the killing of living specimens.

Since these effects are varied and have as yet not been studied in detail, no more can be done here than to mention them and call them to the attention of the research worker who may be interested in investigating some specimen in which one or more of these effects occur.

SERVICE PARTS LIST
RCA ELECTRON MICROSCOPE
TYPES EMU-1, EMU-2, EMU-2A
MAIN ASSEMBLY

Symbol No.	Stock No.	Description	Dwg. No.
A-6	48495	Clock	430502-501
S-1A-1B S-2A-2B S-17A-17B S-18A-18B S-10A-10B	48337	Interlock Switches (male and female section)	
V-12	47744	Thermocouple Gauge (EMU-1 and EMU-2)	427435-1
V-12	51164	Thermocouple Gauge (EMU-2A)	439416-1
X-40 X-41	48254	Connector—Male for condenser and obj. coil	878441-1
		DIAL ASSEMBLY	
	48478	Crystal—Dial	890381-1
	48479	Dial	24670-1
	48480	Pointer	890380-2
	48481	Spring	718955-27
		INTERMEDIATE VIEWING SCREEN HOUSING	
	47751	Housing—Intermediate viewing screen (complete)	878516-501
	47127	Gasket—Intermediate viewing screen window	613792-41
	47753	Gasket—Intermediate viewing screen housing gasket	613792-24
	47752	Ring—Window retaining	870448-2
	47754	Screen—Intermediate viewing housing	859388-2
	47129	Window—Intermediate viewing screen	870447-1
	49022	Aperture—Objective pole piece aperture	886416-1
	47760	Bushing—Control knob bracket	878754-1
	47695	Cable—Grounding	891403-501
	47761	Collar—Control knob bracket	891401-1
	47696	Cushion—Column end piece	891197-1
	47697	Cushion—Column shock mtg.	891197-2
	47742	Cushion Assembly—Column	891199-501
	47745	Gasket—External manifold	613792-59
	48003	Hose—Dehydrator to valve block	891102-2
	47746	Hose—Vacuum pump (EMU-1 and EMU-2)	891132-3
	47748	Hose—Water	891102-1
	48016	Knob—Stage control	891467-501
	48796	Magnifier	427459-501
	47757	Manifold—External	442054-1
	48797	Manifold—Internal (cond. coil—specimen chamber)	890331-501
	48453	Bellows—Internal manifold bellows (condenser coil to specimen chamber)	890333-1
	47753	Gasket—Internal manifold gasket	613792-24
	48452	Spring—Internal manifold spring (condenser coil to specimen chamber)	427496-2
	48798	Manifold—Internal (obj. coil—intermediate viewing screen housing)	427248-501
	44052	Bellows—Internal manifold bellows (obj. coil to inter. screen)	859962-2
	47753	Gasket—Internal manifold gasket	613792-24
	47755	Head—Internal manifold head (obj. coil to inter. screen)	878509-1
	47756	Spring—Internal manifold spring (obj. coil to inter. screen)	718955-23
	44116	Mounting—Lord—Rear column support	834180-7
	47749	Screen—Intermediate viewing	878488-1
	47922	Shaft—Flexible—Dial indicator	891396-1
	47921	Shaft—Flexible stage control	427237-501
	47747	Stop Cock—Glass (3-way) (EMU-1 only)	427444-1

CONTROL PANEL ASSEMBLY

Symbol No.	Stock No.	Description	Dwg. No.
		UPPER CONTROL PANEL	
A-1 to A-4	31480	Pilot Lamp—6-8 v.	61114-22
C-15	18416	Capacitor—1.0 mfd., 150 v.	72043-533
R-11	3058	Resistor—100,000 ohms, 1 w.	78728-86
R-12	48184	Resistor—750 ohms, 10 w.	427230-34
R-13	48185	Resistor—41.6 ohms, 1 w.	891402-6
R-22	48809	Resistor—6,000 ohms, 25 w.	427230-22
R-23	48192	Resistor—400 ohms, 20 w.	878434-1
R-24	39380	Resistor—27 ohms, 1 w.	78728-43
R-26	48193	Resistor—800 ohms, 25 w.	427230-31
R-27	Same as R-26		
R-57	30495	Resistor—47,000 ohms, 1 w.	78728-82
R-61	48194	Resistor—4 ohms, 1 w.	891402-2
R-66	48209	Resistor—2000 ohms, 25 w.	427230-32
R-71	Same as R-26		
R-72	48771	Resistor—1 meg., 1 w.	891029-5
R-73	Same as R-26		
R-100	48192	Resistor—400 ohms, 20 w.	878434-1
S-3, 4	48904	Switch—Panel lights and main power DPST	878368-5
S-5	48238	Switch—Cond. OFF	427246-1
S-7	47118	Switch—Diff. OFF proj.	427247-1
S-8	48905	Switch—H.V. SPST	878368-4
S-11	48240	Switch—Test	427472-1
S-12	48238	Switch—Off. obj.	427246-1
S-13	48906	Switch—Room lights—SPDT	878368-6
V-9		Neon Indicator	RCA #991
V-25	Same as V-9		
X-1	48250	Socket—V-9	878367-2
X-2	48250	Socket—V-25	878367-2
X-4	34449	Socket—A-1	39026-505
X-5, 6, 7	Same as X-4		
X-68	43377	Socket	844041-505
X-69	48253	Socket	891473-1
X-70	48259	Socket	878746-3
X-71	43377	Socket	844041-505
	28000	Knob	717296-503
		LOWER CONTROL PANEL	
M-1	46028	Meter—Fore pressure	426590-2
M-2, 3	46030	Meter—Column pressure	426590-4
M-4	46032	Meter—Test	426590-6
R-19	48188	Rheostat—1000 ohms, 25 w. (EMU-1 and EMU-2)	415457-23
R-19	48208	Rheostat—10,000 ohms, 50 w. (EMU-2A)	878370-3
R-21	48208	Rheostat—10,000 ohms, 50 w.	878370-3
R-25	48188	Rheostat—Diff.—Focus	415457-23
R-63	48207	Resistor—3300 ohms, 10 w.	878435-13
R-64	48208	Rheostat—10,000 ohms, 50 w.	878370-3
R-70	48210	Rheostat—8000 ohms, 50 w.	878370-1
R-74	48211	Resistor—250 ohms, 10 w.	878435-2
R-75	48212	Resistor—14 ohms, 1 w.	891402-13
R-76	48213	Resistor—16 ohms, 1 w.	891402-14
R-77	48214	Resistor—18 ohms, 1 w.	891402-15
R-78	48215	Resistor—20 ohms, 1 w.	891402-5
R-79	48216	Resistor—23 ohms, 1 w.	891402-16
R-80	48217	Resistor—26 ohms, 1 w.	891402-17
R-81	48218	Resistor—30 ohms, 1 w.	891402-18
R-82	48219	Resistor—36 ohms, 1 w.	891402-19
R-83	48185	Resistor—41.6 ohms, 1 w.	891402-6
R-84	48221	Resistor—51 ohms, 1 w.	891402-20
R-85	48222	Resistor—63 ohms, 1 w.	891402-21
R-86	48223	Resistor—79 ohms, 1 w.	891402-22
R-87	48224	Resistor—103 ohms, 1 w.	891402-23
R-88	48225	Resistor—137 ohms, 1 w.	891402-24
R-89	48226	Resistor—198 ohms, 1 w.	891402-25
R-90	48227	Resistor—304 ohms, 1 w.	891402-26
R-91	48228	Resistor—523 ohms, 1 w.	891402-27
R-92	48229	Resistor—1150 ohms, 1 w.	891402-28
R-93	48230	Resistor—4440 ohms, 1 w.	891402-29
R-101, 102	48234	Resistor—180 ohms, 1 w.	82284-141
R-103	43006	Resistor—270 ohms, 1 w.	82284-145

Symbol No.	Stock No.	Description	Dwg. No.
		LOWER CONTROL PANEL—Continued	
R-104	38883	Resistor—330 ohms, 1 w.	82284-147
R-105	Same as R-101		
R-106	Same as R-103		
R-107	48811	Resistor—390 ohms, 1 w.	82284-149
R-108	38877	Resistor—1000 ohms, 1 w.	82284-159
R-109, 110	Same as R-101		
R-111	Same as R-103		
R-114	Same as R-104		
R-127	13097	Resistor—10,000 ohms, 1 w. (EMU-2A only)	78728-183
S-9	46066	Switch—Focus 1	878461-1
S-14	48242	Switch—Magnif.	427473-1
	27990	Knob	717296-502

TOP CHASSIS ASSEMBLY

Symbol No.	Stock No.	Description	Dwg. No.
C-17	48812	Capacitor—0.1 mfd., 500 v.	72043-540
C-18 to C-20	18416	Capacitor—1.0 mfd., 150 v.	72043-533
C-21	30847	Capacitor—.05 mfd., 300 v.	72043-502
C-22	30859	Capacitor—.025 mfd., 1000 v.	72043-532
C-25	48163	Capacitor—.01 mfd., 1200 v.	891363-1
C-32	64735	Capacitor—.005 mfd., 500 v.	72043-537
C-33	Same as C-17		
C-34	30860	Capacitor—0.5 mfd., 200 v.	72043-523
C-35	48165	Capacitor—.0015 mfd., 500 v.	72073-544
C-36	48812	Capacitor—0.1 mfd., 500 v.	72043-540
C-37	18416	Capacitor—1.0 mfd., 150 v.	72043-533
C-38, 39	Same as C-36		
C-40	48160	Capacitor—.001 mfd., 500 v.	72073-527
C-41	48166	Capacitor—.005 mfd., 500 v.	72074-513
C-42	Same as C-17		
C-43	48813	Capacitor—.004 mfd., 1200 v.	891363-4
C-45	12724	Capacitor—120 mmfd.	722013-525
K-2	50792	Relay—Overload	430560-501
L-8	48815	Coil—Osc.	426612-501
L-9	28017	Coil—Choke	900526-502
L-10	48178	Coil—Choke	890305-1
R-15	30735	Resistor—560 ohms, 1 w.	78728-59
R-17	48187	Resistor—200 ohms, 10 w.	878435-12
R-18	Same as R-15		
R-28	33554	Resistor—820,000 ohms, 1 w.	78728-97
R-29	48194	Resistor—4 ohms, 1 w.	891402-2
R-30	5164	Resistor—560 ohms, ½ w.	78727-59
R-31	48195	Resistor—2500 ohms, 50 w.	427230-6
R-32	48196	Resistor—500 ohms, 25 w.	427230-3
R-33	14583	Resistor—220,000 ohms, ½ w.	78727-90
R-34	48186	Resistor—100 ohms, 10 w.	427230-1
R-35	32726	Resistor—560,000 ohms, 1 w.	78728-95
R-36	48198	Resistor—5000 ohms, 10 w.	878435-4
R-37	48771	Resistor—1 meg., 1 w.	891029-5
R-38	32723	Resistor—10 ohms, 1 w.	78728-38
R-39	31215	Resistor—100 ohms, 1 w.	78728-50
R-40	48194	Resistor—4 ohms, 1 w.	891402-2
R-41	48201	Resistor—500 ohms, 10 w.	878435-3
R-42	44364	Resistor—820,000 ohms, 2 w.	78724-97
R-46	48816	Resistor—10,000 ohms, 1 w.	878435-19
R-47	48204	Resistor—18,000 ohms, 10 w.	878435-5
R-48	30651	Resistor—270,000 ohms, ½ w.	78727-91
R-49	30409	Resistor—27,000 ohms, ½ w.	78727-79
R-50	30151	Resistor—18,000 ohms, 1 w.	78728-77
R-51	3252	Resistor—100,000 ohms, ½ w.	78727-86
R-52	48205	Resistor—6.5 meg., 2 w.	878432-2
R-53	44364	Resistor—820,000 ohms, 2 w.	78724-97
R-54	3058	Resistor—100,000 ohms, 1 w.	78728-86
R-55	13097	Resistor—10,000 ohms, 1 w.	78728-74
R-56	30149	Resistor—8200 ohms, 1 w.	78728-73
R-58	33554	Resistor—820,000 ohms, 1 w.	78728-97
R-59	30149	Resistor—8200 ohms, 1 w.	78728-73
R-60	14583	Resistor—220,000 ohms, ½ w.	78727-90

TOP CHASSIS ASSEMBLY—Continued

Symbol No.	Stock No.	Description	Dwg. No.
R-67	13097	Resistor—10,000 ohms, 1 w.	78728-74
R-68	48194	Resistor—4 ohms, 1 w.	891402-2
R-69	48817	Resistor—35,000 ohms, 10 w.	878435-14
R-94	34765	Resistor—100 ohms, ½ w.	727834-135
R-95	48232	Resistor—10,000 ohms, 75 w.	427230-9
R-96	30735	Resistor—560 ohms, 1 w.	78728-59
R-97	Same as R-94		
R-98	Same as R-96		
R-99	Same as R-94		
R-117	30736	Resistor—22,000 ohms, 1 w.	78728-78
R-118	48196	Resistor—500 ohms, 25 w.	427230-3
T-4	48245	Transformer	901389-501
T-7	46033	Transformer	878736-1
T-8	64306	Transformer	878739-1
X-3	48250	Socket—Tube	878367-2
X-27	18007	Socket—Tube	844041-503
X-28	19458	Socket—Tube	844933-3
X-29	18007	Socket—Tube	844041-503
X-30	19395	Socket—Tube	844933-2
X-31	19458	Socket—Tube	844933-3
X-32	Same as X-31		
X-33	Same as X-30		
X-34	Same as X-29		
X-35, 36, 37	Same as X-34		
X-38	Same as X-30		
X-39	48253	Socket—Cable W-3	891473-1
X-53	48257	Socket—Cable W-12	891495-3
	69693	Insulator—R-52	426765-1
	69480	Insulator—R-37	426766-1

BOTTOM CHASSIS ASSEMBLY

Symbol No.	Stock No.	Description	Dwg. No.
A-5	48818	Lamp—115 volts, 1 w.	849546-9
C-1	48157	Capacitor—1500 volts, 1 mfd.	878373-1
C-2	Same as C-1		
C-3	48158	Capacitor—1 mfd., 2000 v.	878374-1
C-4 to C-11	48159	Capacitor—125 mfd., 350 v.	86060-6
C-12	48160	Capacitor—.001 mfd., 500 v.	72073-527
C-13	48812	Capacitor—0.1 mfd., 500 v.	72043-540
C-14	48161	Capacitor—1.0 mfd., 600 v.	890311-1
C-16	18416	Capacitor—1.0 mfd., 150 v.	72043-533
F-1	48819	Fuse—15 amps.	99043-4
F-2	Same as F-1		
F-7	10907	Fuse	55544-4
K-1	53915	Relay—Vac. interlock	445262-1
L-1, 2	46045	Coil—Choke	878371-1
L-3	46044	Coil—Choke	878375-2
L-4, 5	46340	Coil—Choke	878375-1
R-1	48820	Resistor—0.8 ohm, 10 w.	878435-15
R-2	48180	Resistor—50,000 ohms, 1 w.	891402-8
R-3	48181	Resistor—80,000 ohms, 1 w.	891402-10
R-4	14583	Resistor—220,000 ohms, ½ w.	78727-90
R-5	32727	Resistor—680,000 ohms, 1 w.	78727-96
R-6, 7	5164	Resistor—560 ohms, ½ w.	78727-59
R-8	48182	Resistor—75,000 ohms, 1 w.	891402-9
R-9	34767	Resistor—2200 ohms, ½ w.	78727-66
R-10	48183	Resistor—660,000 ohms, 4 w.	878437-1
R-14	48186	Resistor—100 ohms, 10 w. (EMU-1 and EMU-2)	427230-1
R-14	52463	Resistor—15 ohms, 10 w. (EMU-2A)	427491-22
R-16	2546	Resistor—1 meg., 1 w.	78728-98
R-20	48189	Resistor—50,000 ohms, 50 w.	427230-35
R-62	48181	Resistor—80,000 ohms, 1 w.	891402-10
R-112	43609	Rheostat—10 ohms, 100 w.	849811-1
R-113	48821	Resistor—5 ohms, 50 w.	427491-1
R-115, 116	18190	Resistor—47 ohms, 1 w.	78728-46
R-119 to R-126	3058	Resistor—100,000 ohms, 1 w. (EMU-2 and EMU-2A)	78728-86
T-1	48243	Transformer	891390-1
T-2	48244	Transformer	878376-1
T-3	46036	Transformer	878377-1

BOTTOM CHASSIS ASSEMBLY—Continued

Symbol No.	Stock No.	Description	Dwg. No.
T-5	48246	Transformer	878372-1
T-6	17692	Transformer	900168-502
T-9	48247	Transformer	878735-1
X-8	23540	Receptacle—Pilot lamp	99014-1
X-9, 10	23540	Receptacle—Fuse	99014-1
X-12	18007	Socket—Tube	844041-503
X-13	Same as X-12		
X-14	18007	Receptacle—Cable W-5	844041-503
X-16, 17	19458	Socket—Tube	844933-3
X-18 to X-23	Same as X-12		
X-24	48251	Receptacle—Cable W-6	878746-1
X-25	Same as X-12		
X-26	48252	Receptacle—Cable W-4	878746-2
X-57 to X-64	45368	Socket—Capacitor	181516-2
X-74	45851	Fuse Holder—Cartridge	844027-2
	69693	Insulator—Porcelain for R-10 and plate leads	426765-1

H. V. UNIT ASSEMBLY

Symbol No.	Stock No.	Description	Dwg. No.
C-24	47933	Capacitor—.006 mfd., 600 v.	891363-3
C-26, C-27, C-28	47934	Capacitor—.0005 mfd.	504400-501
C-29	47935	Capacitor—.025 mfd., 50,000 v.	718572-1
C-30	Same as C-26		
C-31	47936	Capacitor—1.0 mfd., 400 v.	72049-538
C-44	47937	Capacitor—.000025 mfd.	504425-501
L-13 includes T-13	47938	Coil—Tank coil and fil. trans. assem.	427255-501
L-15	48468	Coil—Ripple trap	427456-501
R-65	47940	Resistor—1000 meg.	869085-1
T-12	47941	Coil—Filament transformer	427256-501
T-13	47938	Part of L-13 and T-13 assem.	
X-48, X-49, X-50	47942	Socket—8013-A tube	878546-1
X-51	48256	Connector—3 contact	891136-1

HIGH VOLTAGE BUSHING

Symbol No.	Stock No.	Description	Dwg. No.
R-43	48202	Resistor—200,000 ohms, 6 w.	859882-1
R-44	48203	Resistor—47 ohms, ½ w.	850981-46
R-45	48203	Same as R-44	
Part of T-10	47351	Coil—Outer coil assem.	718956-501
Part of T-10	48035	Coil—Inner coil assem.	430518-501
X-73	48261	Connector—3 contact, male	891494-1

ELECTRON GUN

Symbol No.	Stock No.	Description	Dwg. No.
	48799	Aperture—Electron gun	859376-1
	440	Bellows—Electron gun or internal bellows	859962-3
	48100	Bushing—Insulating filament mtg. plate	802332-1
	48103	Coupling—Worm gear	891027-1
	44511	Filament Assembly—Radiotron FM-2379 (V-31)	
	48140	Gasket—Glass shield bottom	613792-61
	48139	Gasket—Glass shield top	613792-60
	48141	Gasket—Gun assembly bottom	613792-65

ELECTRON GUN—Continued

Symbol No.	Stock No.	Description	Dwg. No.
	48803	Gasket—Internal bellows	613792-58
	48142	Gasket—Window	613792-62
	48102	Gear Assembly—Filament adjusting	859371-501
	48109	Internal Bellows Assembly Complete	878517-501
	48107	Knob Assembly—Gun lateral adjusting	890300-501
	48105	Plug—Adjusting shaft spring	890306-1
	48111	Screen—Window	859388-1
	48106	Screw—Lateral adjusting	891498-1
	65977	Screw—#4-40 x 1/8" Allen set screw for electron gun filament assembly	843365-41
	44732	Screw—#8-32 x 1/8" Allen set screw for worm gear coupling	843365-11
	48804	Screw—#10-32 x 5/8" socket head screw for electron gun	881919-13
	48101	Seal—Vacuum electron gun	859370-501
	48104	Shaft—Lateral adj. self-regulating	878499-1
	48108	Shield—Glass shield less top and bottom plates	859392-1
	48800	Sleeve—Cathode sleeve	427245-1
	48801	Spring—Internal bellows	427496-1
	48802	Spring—Lateral adjustment shaft	718955-3
	48110	Window—Electron gun	859387-1
	48112	Worm Drive Assembly	415344-7

SPECIMEN CHAMBER ASSEMBLY

Symbol No.	Stock No.	Description	Dwg. No.
	48406	Cam Assembly—Door knob shaft and cam	891186-501
	48483	Cap—Specimen holder cap	892010-1
	48378	Gasket—Specimen chamber bottom	613792-71
	48384	Gasket—Specimen chamber-door	613792-86
	48408	Gasket—Door knob shaft	613792-85
	48374	Gear—Micrometer gear	891164-1
	48405	Knob—Specimen chamber door	891176-1
	48387	Lifter Assembly—Specimen lifter	878580-501
	47985	Packing—Door knob shaft and micrometer screw	878391-1
	47628	Screen—Specimen screen	891152-1
	48377	Screw—Micrometer screw	891166-1
	48376	Shaft—Worm gear	891177-1
	48404	Specimen Holder Assembly (Stereo)	891194-501
	48390	Specimen Holder Assembly (Standard)	891193-501
	48407	Spring—Door knob shaft	718955-18
	48805	Spring—Knob limit pin	718955-10
	48379	Spring—Micrometer gear—L.H.	890320-1
	48380	Spring—Micrometer gear—R.H.	890320-2
	48386	Spring—Micrometer screw	718995-13
	48385	Spring—Hold down spring	890334-1
98495	48381	Spring Assembly—With 2 anvils	878726-501
98493	48382	Spring Assembly—With 2 anvils (1 slotted)	878726-502
98494	48383	Spring Assembly—With 1 anvil	878726-503
	48375	Worm—Micrometer gear	891164-2

DIFFRACTION UNIT

Symbol No.	Stock No.	Description	Dwg. No.
X-42	48255	Plug—Male	878440-1
	48807	Gasket—Bottom	613792-66
	47127	Gasket—Window	613792-41
	47129	Window	870447-1

STAGE ASSEMBLY

Symbol No.	Stock No.	Description	Dwg. No.
	47149	Aperture—Reflection	870440-2
	47116	Ball—Axial adj. rod	76757-18
	48032	Bushing—Packing pressure	878536-1
	48483	Cap—Specimen holder	892010-1
	47110	Gasket—Pushrod	613792-43
	48027	Gasket—Stage	613792-73
	48031	Hand Wheel—Less handles	878719-1
	47115	Handle—For handwheel	878533-1
	46999	Packing—Push rods	878391-2
	47105	Pin—Swivel pin—Tilting pushrod	878535-1
	47103	Push Rod Assembly—Rot. and axial adj.	870430-502
	47102	Push Rod Assembly—Tilting	870430-501
	48028	Ring—Gasket thrust ring	870411-3
	47628	Screen—Specimen	891152-1
	47117	Shaft—Axial adj.	870432-3
	47106	Specimen Holder—Reflection	878527-1
	47107	Specimen Holder—Transmission	870440-1
	46998	Spring—Conical—Tilting push rod	878534-1
	46997	Spring—Helical—Push rod packing	718955-9
	47113	Thumbwheel—Angular adj.	878740-1
	47111	Thumbwheel—Spec. rotation	870429-1
	47112	Thumbwheel—Transverse adj.	878741-1

VIEWING CHAMBER ASSEMBLY

Symbol No.	Stock No.	Description	Dwg. No.
V-13	51165	Ionization Gauge	439409-501
	48021	Bracket—Rack	891123-1
	48013	Cable Release	878492-1
	47735	Gasket—(Bottom)	613792-57
	53631	Gasket—(Ionization gauge)	613792-87
	48009	Gasket—Pinion sleeve	613792-84
	48012	Gasket (Window)	613792-79
	48007	Gear Assembly—For screen	878477-501
	48014	Magnet—Ionization gauge	427438-1
	47985	Packing—Viewing screen shaft	878391-1
	48008	Rack—Screen moving	878479-1
	48656	Screen—Ionization gauge	859388-3
	48005	Screen—Viewing complete	427228-501
	48015	Spring—Pinion	891471-1
	48010	Spring—Pinion shaft packing	718955-13
	48006	Window—Viewing chamber	878320-1
	51579	Fluorescent Coating—25 gm. bottle	

PHOTO CHAMBER ASSEMBLY

Symbol No.	Stock No.	Description	Dwg. No.
	47986	Bearing—Roller bearing—Pinion shaft	855201-4
	47995	Gasket—Door	613792-80
	47981	Gasket—Knob	613792-67
	47989	Handle—Photo chamber door	878314-1
		B-1 Taper Pin	59127-21
	47991	Hinge—Photo chamber door	878319-1
		B-1 Pin	878335-2
	47987	Gear—Photo chamber	878399-1
	17268	Knob Assem.—Photo chamber	712336-505
	47990	Latch—Photo chamber door latch	878315-1
	47985	Packing—Knob shaft	878391-1
	47994	Pin—Cassette stop pin	878568-1
	47993	Rack—Carriage—Photo chamber	878381-1
	47992	Screw—Stop screw—Photo chamber door	878318-1
	47984	Shaft—Knob	878401-1
	48808	Shaft—Pinion	878402-1
	47983	Spring—Packing pressure	718955-12
	47982	Spring—Cassette stop pin	718955-26
	MI-12977A	Cassette and cover	

VALVING MECHANISM

Symbol No.	Stock No.	Description	Dwg. No.
		VALVE DRIVE	
	47928	Bushing and Bearing Assembly	891397-1
	51294	Crank Assembly (EMU-2 and EMU-2A only)	878455-502
	47927	Crank Assembly (EMU-1 only)	878455-501
	51295	Spring—Valve drive (EMU-2 and EMU-2A only)	718955-29
	47930	Joint—Universal (EMU-1 only)	891398-2
	47929	Spring—Valve drive (EMU-1 only)	878457-1
		VALVING MECHANISM	
S-6	43177	Switch—Micro switch	892032-1
	47720	Arm Assem.—"D" valve	878420-501
	47721	Arm Assem.—Indent wheel	878420-502
	47731	Bearings—Roller bearing—3/8" I.D. x 9/16" O.D.	855201-6
	47732	Bearings—Roller bearing—3/16" I.D. x 11/32" O.D.	855201-7
	47730	Bearings—Roller bearing—5/16" I.D. x 1/2" O.D.	855201-5
	47713	Bellows—Metallic bellows for "A" and "B" valve	859962-12
	47705	Bellows—Metallic bellows for "C" valve	859962-13
	47725	Cam—"A" valve	718673-3
	47726	Cam—"B" valve	718673-4
	47723	Cam—"C" valve	718673-1
	47724	Cam—"D" valve	718673-2
	47718	Coupling—(for flex. shaft)	891295-1
	48736	Gasket—"D" valve shaft	613792-51
	47716	Gasket—"A" and "B" valve (inner)	613792-53
	47733	Gasket—"A" and "B" valve (outer) and air tubes	613792-54
	47708	Gasket—for "C" valve (inner)	613792-52
	47734	Gasket—for "C" valve (outer)	613792-55
	47735	Gasket—(to column and oil diff. pump)	613792-57
	47729	Gear—Large	878397-2
	47728	Gear—Small	878397-1
	47930	Joint—Universal joint (EMU-1 only)	891398-2
	47736	Nipple—Hose	891399-1
	47738	Shaft—"A" and "B" cams	878424-2
	47710	Shaft—"A" and "B" valve	891388-1
	47702	Shaft—"C" valve	878396-1
	47737	Shaft—"C" and "D" and indent cams	878424-1
	47739	Shaft—Drive	878424-3
	47740	Spring—Indent arm	878457-2
	47727	Tubing Assem. (air lines) (EMU-1 only)	878433-501
	47709	Valve Assembly—"A" and "B" valve	878411-501
	47714	Spring—for "A" and "B" valve	718955-15
	47711	Valve Bushing for "A" and "B"	878406-1
	47715	Valve end for "A" and "B" valve	878393-1
	47712	Valve Plate—"A" and "B" valve	878404-1
	47701	Valve Assem.—"C" valve	878410-501
	47706	Spring—for "C" valve	718955-14
	47703	Valve bushing for "C" valve	878405-1
	47707	Valve End—for "C" valve	878394-1
	47704	Valve Plate—for "C" valve	878404-2
	47717	Valve Disc Assem.—"D" valve	858486-501
	47741	Spring—"D" valve	718955-16
	47722	Wheel—Detent wheel	878450-1
	47719	Yoke—"D" valve	878413-1

VACUUM PUMP

Symbol No.	Stock No.	Description	Dwg. No.
	48843	Belt—Motor drive belt	Pt. of 718951-1
	48844	Motor—50 cycle—115 volt-230 volt	Pt. of 718951-2
	48842	Motor—60 cycle—115 volt-230 volt	Pt. of 718951-1
	48845	Oil—Vacuum pump oil	890324-1
	48841	Pump—Vacuum pump only (A-7) (less motor, pulley and belt)	Pt. of 718951-1

BATTERY BOX (For Cabinet)

Symbol No.	Stock No.	Description	Dwg. No.
B-1 to B-8	47213	Battery—45 volts	891434-1
B-9	47215	Battery—22½ volts	891435-1
B-10	47213	Battery—45 volts	891434-1
B-11	47214	Battery—22½ volts	891455-1
F-4, 5, 6	3748	Fuse—½ amp.	55544-11
J-1	47943	Plug—Battery box	878438-1
J-3 to J-10	47943	Plug—Battery box	878438-1
X-44 to X-46	45851	Fuse Holder	844027-2

OIL DIFFUSION PUMP

Symbol No.	Stock No.	Description	Dwg. No.
S-15	47698	Thermoswitch	891105-1
X-67	47700	Plug	891106-1
	47699	Coupling	891104-1

CABLES AND CONNECTORS

Symbol No.	Stock No.	Description	Dwg. No.
W-1	48822	Cable—Control panel to coils	427476-501
J-11-12	48168	Connector—Female for Cable W-1	878362-1
J-13	48836	Connector—Female for Cable W-1	878364-1
J-14	35383	Connector—Male for Cable W-1	413691-8
W-2	48823	Cable—Top chassis to battery box	427257-501
J-24	48838	Connector—Male for Cable W-2	890396-1
W-3	48824	Cable—Control panel to top chassis	427477-501
J-17-30	48169	Connector—Female for Cable W-3	891472-1
W-4	48825	Cable—Top chassis to bottom chassis	427478-501
J-20	48170	Connector—Female for Cable W-4	878745-2
W-5	48826	Cable—Column to bottom chassis	427479-501
J-19	35383	Connector—Male for Cable W-5	413691-8
W-6	48827	Cable—Control panel to bottom chassis	427480-501
J-16	35383	Connector—Male for Cable W-6	413691-8
J-18	48837	Connector—Female for Cable W-6	878745-1
J-2	48167	Connector—Female for Cable W-6	878745-3
W-7	48828	Cable—Thermocouple to bottom chassis	427481-501
J-25	35383	Connector—Male for Cable W-7	413691-8
W-8	48829	Cable—Bottom chassis to diffusion pump	427482-501
J-26	48174	Connector—Female for Cable W-8	890317-1
W-9	48830	Cable—High voltage unit to top chassis	427497-501
J-29	48839	Connector—Female for Cable W-9	891475-1
W-10	48831	Cable—High voltage unit to top chassis	427484-501
W-11	48832	Cable—High voltage unit to top chassis	427485-501
J-22	48172	Connector—Male for Cable W-11	878750-1
W-12	48833	Cable—Top chassis to high voltage bushing	427486-501
J-21	48171	Connector—Male for Cable W-12	891495-2
J-27	48175	Connector—Female for Cable W-12	891495-1
W-13	48834	Cable—Interlock	427489-501
W-14	48835	Cable—Interlock	427488-501
J-23	48173	Connector—Female—Connects into X-51	891135-1

MISCELLANEOUS MATERIAL AND PARTS

Symbol No.	Stock No.	Description	Dwg. No.
	47925	Box—Utility box	891425-1
	48388	Centering Pin—For stage	891350-1
	51579	Coating—Fluorescent 1 oz. (powder)	
	46605	Film Making Kit—Complete	
	48287	Grease—Cello grease	890322-1
	48030	Grease—Lubriko grease	891458-1
	47924	Lifter—Pole piece	718950-501
	48387	Lifter—Spec. holder	878580-501
	45924	Oil—Diffusion pump	
	47923	Rod—Filament adjusting	891028-501
	47790	Tongs—Internal manifold	427266-501
	44218	Tongs—Pole piece	426501-1
	46698	Wax—Picein or apiezon wax	890321-1
	46699	Allen Wrench—#4 screw	828505-14
	19996	Allen Wrench—#6 screw	828505-13
	14991	Allen Wrench—#8 screw	828505-12
	26581	Allen Wrench—#10 screw	828505-1
	22112	Allen Wrench—¼" screw	828505-2
	22113	Allen Wrench—5/16" screw	828505-3
	22111	Allen Wrench—⅜" screw	828505-4
	62967	Allen Wrench—5/16" cap screw	828505-5
	64179	Allen Wrench—⅜" cap screw	828505-7
	48389	Wrench—Cassette control nut	891409-1
	47926	Wrench—Spanner	718950-6

CALCULATION AND TEST SHEET

D.C. SUPPLY 1240 VOLTS 680 VOLTS 410 VOLTS
88 M.A. 115 M.A. 150 M.A.

HIGH VOLTAGE SUPPLY 50,000 VOLTS .5 M.A.

A.C. SUPPLY-115 VOLTS-1000 WATTS

ELECTRON MICROSCOPE, TYPES EMU-1 AND EMU-2

TUBE NO.	TUBE TYPE	FUNCTION	OPER. CONDITION	VOLTS E PLATE	E SCREEN	E CATH.	E GRID	E HEATER	E FILTER	AMPS I PLATE	I SCREEN	I CATH.	I HEATER	PLATE RESISTOR OHMS	PLATE RESISTOR WATTS	FILTER RESISTOR OHMS	FILTER RESISTOR WATTS	SCREEN RESISTOR OHMS	SCREEN RESISTOR WATTS	CATHODE RESISTOR OHMS	CATHODE RESISTOR WATTS	PLATE WATTS	SCREEN WATTS	TUBE NO.
V-1	1616	RECTIFIER	MAX.BEAM	1180AC	—	1240	—	2.5	—	.088	—	.088	5	—	—	—	—	—	—	—	—	110	—	V-1
V-2	1616	RECTIFIER	MAX.BEAM	1180AC	—	1240	—	2.5	—	.088	—	.088	5	—	—	—	—	—	—	—	—	110	—	V-2
V-3	5R4GY	RECTIFIER	NORMAL	500AC	—	690	—	5	—	.115	—	.115	2	—	—	—	—	—	—	—	—	80	—	V-3
V-4	5R4GY	RECTIFIER	NORMAL	500AC	—	470	—	5	—	.150	—	.150	2	—	—	—	—	—	—	—	—	70	—	V-4
V-5	VR-150	VOLT. REG.	NORMAL	152	—	0	—	—	—	.006	—	.006	—	—	—	—	—	—	—	—	—	.9	—	V-5
V-6	6SF5	D.C. AMP.	NORMAL	350	—	151.5	150	6.3	—	.00045	—	.00045	.0045	680,000	.13	—	—	—	—	—	—	.16	—	V-6
V-7	6L6	SERIES REG.	NORMAL	700	700	390	350	6.3	—	.057	.005	.062	.9	—	—	—	—	560	.002	—	—	17.5	1.5	V-7
V-8	6L6	SERIES REG.	NORMAL	700	700	390	350	6.3	—	.057	.005	.062	.9	—	—	—	—	560	.002	—	—	17.5	1.5	V-8
V-9	991	INDICATOR	MAXIMUM CURRENT	160	—	100	—	—	—	.002	—	.002	—	—	—	—	—	—	—	—	—	.12	—	V-9
V-10	6H6	RECTIFIER	MAXIMUM CURRENT	220	—	200	—	6.3	—	.0002	—	.0002	.0004	1 MEG.	.04	—	—	—	—	—	—	.004	.27	V-10
V-11	6L6	AMPLIFIER	NORMAL	60	70	0	-5	6.3	—	.008	.004	.012	.012	660,000	.66	—	—	—	—	—	—	.47	—	V-11
V-12		THERMOCOUPLE GAGE	NORMAL	—	—	100	—	.4	—	—	—	—	0.9	—	—	—	—	—	—	—	—	—	—	V-12
V-13		ION. GAGE	MAXIMUM CURRENT	2150AC	—	—	—	—	—	.001	—	.001	—	—	—	—	—	—	—	—	—	—	—	V-13
V-14	6Y6-G	SERIES REG.	NORMAL	410	410	266	256	6.3	—	.085	.005	.090	1.25	—	—	—	—	560	.014	—	—	12	.7	V-14
V-15	811	SERIES REG.	MAX.BEAM	1240	—	700	730	6.3	—	.086	—	.106	4	—	—	—	—	—	—	—	—	46	.01	V-15
V-16	12SJ7	D.C. AMP.	NORMAL	253	45	0	-2.75	12.6	—	.00018	.0001	.0003	0.15	820,000	.02	—	—	560	.014	5000	.2	2.0	1.3	V-16
V-17	807	SERIES REG.	MAX.BEAM	1240	1000	730	700	6.3	—	.040	.005	.045	0.9	100	.15	—	—	—	—	4	.1	50	—	V-17
V-18	811	OSCILLATOR	MAX.BEAM	700	—	1	-34.0	6.3	—	.070	—	.100	4	10	.06	—	—	—	—	SEE V-18		63	—	V-18
V-19	811	OSCILLATOR	MAX.BEAM	700	—	1	-36.5	6.3	—	.090	—	.126	4	—	—	—	—	—	—	—	—	.6	.78	V-19
V-20	807	D.C. AMP.	NORMAL	700	310	155	133	6.3	—	.001	.005	.005	.006	560,000	.56	—	—	560	.014	—	—	2.1	—	V-20
V-21	VR-150	VOLT. REG.	NORMAL	155	—	0	—	—	—	.014	—	.014	—	—	—	—	—	—	—	—	—	.13	.05	V-21
V-22	12SJ7	D.C. AMP	NORMAL	133	150	0	-7.4	12.6	—	.00095	.00032	.0013	0.15	270,000	.24	—	—	18,000	.16	—	—	11.5	.63	V-22
V-23	6L6	SERIES REG.	NORMAL	390	365	154	145	6.3	—	.049	.003	.052	0.9	—	—	—	—	8200	.076	—	—	.05	.002	V-23
V-24	12SJ7	D.C. AMP.	NORMAL	150	22	0	-2.9	12.6	—	.0003	.0001	.0004	0.15	820,000	.073	—	—	—	—	—	—	.1	—	V-24
V-25	991	INDICATOR	MAXIMUM CURRENT	63	—	0	—	—	—	.0017	—	.0017	—	—	—	—	—	—	—	—	—	.05	—	V-25
V-26	991	METER PROTECTION	PEAK	94	—	0.5	—	—	—	.0005	—	.0005	—	—	—	—	—	—	—	—	—	.05	—	V-26
V-27	807	OSCILLATOR	MAX.BEAM	270	128	0	-40	6.3	—	.048	.0045	.0525	0.9	—	—	—	—	33,000	.65	4	.0015	8.1	.58	V-27
V-28	8013A	RECTIFIER	NORMAL	-16,700	—	54	—	2.5	—	.0007	—	.0007	5	—	—	—	—	—	—	—	—	11.7	—	V-28
V-29	8013A	RECTIFIER	NORMAL	-33,300	—	-16,700	—	2.5	—	.0007	—	.0007	5	—	—	—	—	—	—	—	—	11.7	—	V-29
V-30	8013A	RECTIFIER	NORMAL	-50,000	—	-33,300	—	2.5	—	.0007	—	.0007	5	—	—	—	—	—	—	—	—	11.7	—	V-30

NOTE:- ALL VOLTAGES MEASURED TO GROUND — EXCEPT HEATER VOLTAGES.

SUB 2 MAY 26,1944 S.M. ZOLLERS

ELECTRON MICROSCOPE, TYPE EMU-2A CALCULATION AND TEST SHEET

D.C. SUPPLY 1240 VOLTS 680 VOLTS 410 VOLTS
88 M.A. 115 M.A. 150 M.A.
HIGH VOLTAGE SUPPLY 50,000 VOLTS .5 M.A.
A.C. SUPPLY-115 VOLTS-1000 WATTS

TUBE NO.	TUBE TYPE	FUNCTION	OPER. CONDITION	VOLTS E PLATE	E SCREEN	E CATH.	E GRID	E HEATER	E FILTER	AMPS I PLATE	I SCREEN	I CATH.	I HEATER	PLATE RESISTOR OHMS	PLATE RESISTOR WATTS	FILTER RESISTOR OHMS	FILTER RESISTOR WATTS	SCREEN RESISTOR OHMS	SCREEN RESISTOR WATTS	CATHODE RESISTOR OHMS	CATHODE RESISTOR WATTS	PLATE WATTS	SCREEN WATTS	TUBE NO.
V-1	1616	RECTIFIER	MAX.BEAM	1180AC	—	1240		2.5	—	.088	—	.088	5									110	—	V-1
V-2	1616	RECTIFIER	MAX.BEAM	1180AC	—	1240	—	2.5	—	.088	—	.088	5									110	—	V-2
V-3	5R4GY	RECTIFIER	NORMAL	500AC	—	690	—	5	—	.115	—	.115	2									110	—	V-3
V-4	5R4GY	RECTIFIER	NORMAL	500AC	—	470	—	5	—	.150	—	.150	2									80	—	V-4
V-5	VR-150	VOLT. REG.	NORMAL	152	—	0	—	—	—	.006	—	.006	—									70	—	V-5
V-6	6SF5	D.C. AMP.	NORMAL	350	—	151.5	150	6.3	—	.00045	—	.00045	0.3	680,000	.13							.9	—	V-6
V-7	6L6	SERIES REG.	NORMAL	700	700	390	350	6.3	—	.057	.005	.062	.9									.16	—	V-7
V-8	6L6	SERIES REG.	NORMAL	700	700	390	350	6.3	—	.057	.005	.062	.9					560	.002			17.5	1.5	V-8
V-9	991	INDICATOR	MAXIMUM CURRENT	160	—	100	—	—	—	.002	—	.002	—					560	.002			17.5	1.5	V-9
V-10	6H6	RECTIFIER	MAXIMUM CURRENT	220	—	200	—	6.3	—	.0002	—	.0002	0.3	1 MEG.	.04							.12	—	V-10
V-11	6L6	AMPLIFIER	NORMAL	60	70	0	-5	6.3	—	.008	.004	.012	0.9									.004	—	V-11
V-12	THERMOCOUPLE GAGE		NORMAL	—	—	—	—	1	—	—	—	—	0.6									.47	.27	V-12
V-13	ION. GAGE		MAXIMUM CURRENT	2150AC	—	100	—	—	—	.001	—	.001	—	660,000	.66							—	—	V-13
V-14	6Y6-G	SERIES REG.	NORMAL	410	410	266	256	6.3	—	.085	.005	.090	1.25					560	.014			12	.7	V-14
V-15	811	SERIES REG.	MAX.BEAM	1240	—	700	730	6.3	—	.086	—	.106	4									46	—	V-15
V-16	12SJ7	D.C. AMP.	NORMAL	253	45	0	-2.75	12.6	—	.00016	.0001	.0003	0.15	820,000	.02							.05	.01	V-16
V-17	807	SERIES REG.	MAX.BEAM	1240	1000	730	700	6.3	—	.040	.005	.045	0.9	100	.15			560	.014	5000	.2	20	1.3	V-17
V-18	811	OSCILLATOR	MAX.BEAM	700	—	1	-34.0	6.3	—	.070	—	.100	4	10	.06					4	.1	50	—	V-18
V-19	811	OSCILLATOR	MAX.BEAM	700	—	1	-36.5	6.3	—	.090	—	.126	4							SEE V-18		63	—	V-19
V-20	807	D.C. AMP.	NORMAL	700	310	155	133	6.3	—	.001	.005	.006	0.9	560,000	.56			560	.014			.6	.78	V-20
V-21	VR-150	VOLT. REG.	NORMAL	155	—	0	—	—	—	.014	—	.014	—									2.1	—	V-21
V-22	12SJ7	D.C. AMP.	NORMAL	133	150	0	-7.4	12.6	—	.00095	.00032	.0013	0.15	270,000	.24			18,000	.16			.13	.05	V-22
V-23	6L6	SERIES REG.	NORMAL	390	365	154	145	6.3	—	.049	.003	.052	0.9	—	—			8200	.076			11.5	.63	V-23
V-24	12SJ7	D.C. AMP.	NORMAL	150	22	0	-2.9	12.6	—	.0003	.0001	.0004	0.15	820,000	.073							.05	.002	V-24
V-25	991	INDICATOR	MAXIMUM CURRENT	63	—	0				.0017	—	.0017	—									.1	—	V-25
V-26	991	METER PROTECTION	PEAK	94	—	0.5	—	—	—	.0005	—	.0005	—									.05	—	V-26
V-27	807	OSCILLATOR	MAX.BEAM	270	128	0	-40	6.3	—	.048	.0045	.0525	0.9					33,000	.65	4	.0015	8.1	.58	V-27
V-28	8013A	RECTIFIER	NORMAL	-16,700	—	54	—	2.5	—	.0007	—	.0007	5									11.7	—	V-28
V-29	8013A	RECTIFIER	NORMAL	-33,300	—	-16,700	—	2.5	—	.0007	—	.0007	5									11.7	—	V-29
V-30	8013A	RECTIFIER	NORMAL	-50,000	—	-33,300	—	2.5	—	.0007	—	.0007	5									11.7	—	V-30

NOTE:- ALL VOLTAGES MEASURED TO GROUND — EXCEPT HEATER VOLTAGES.

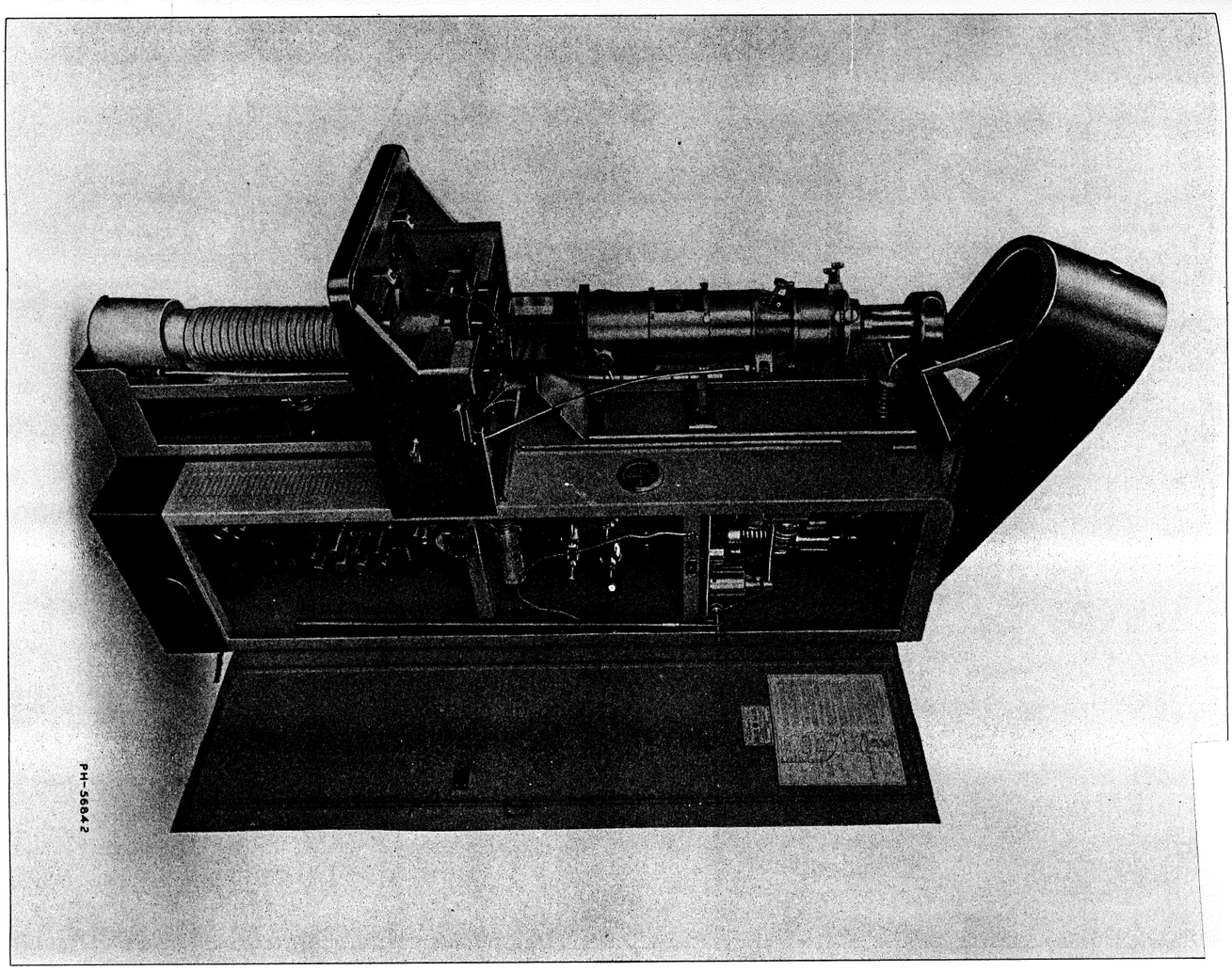


Figure 17—Electron Microscope, Type EMU, Right Side View, Door and Hood Open, Column and Diffusion Pump Exposed, Control Panel Removed

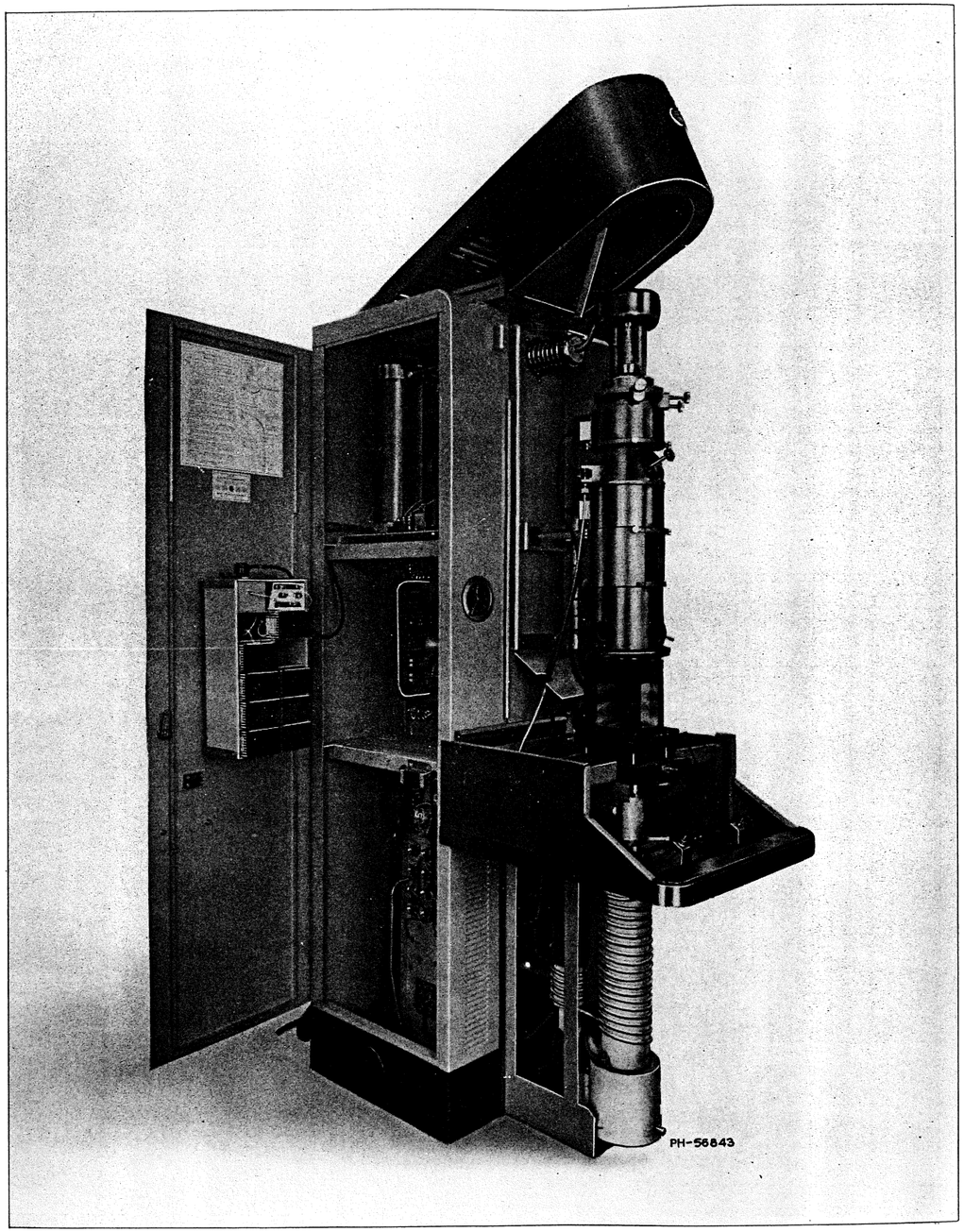


Figure 18—*Electron Microscope, Type EMU, Left Side View, Door and Hood Open, Column and Diffusion Pump Exposed, Control Panel Removed*

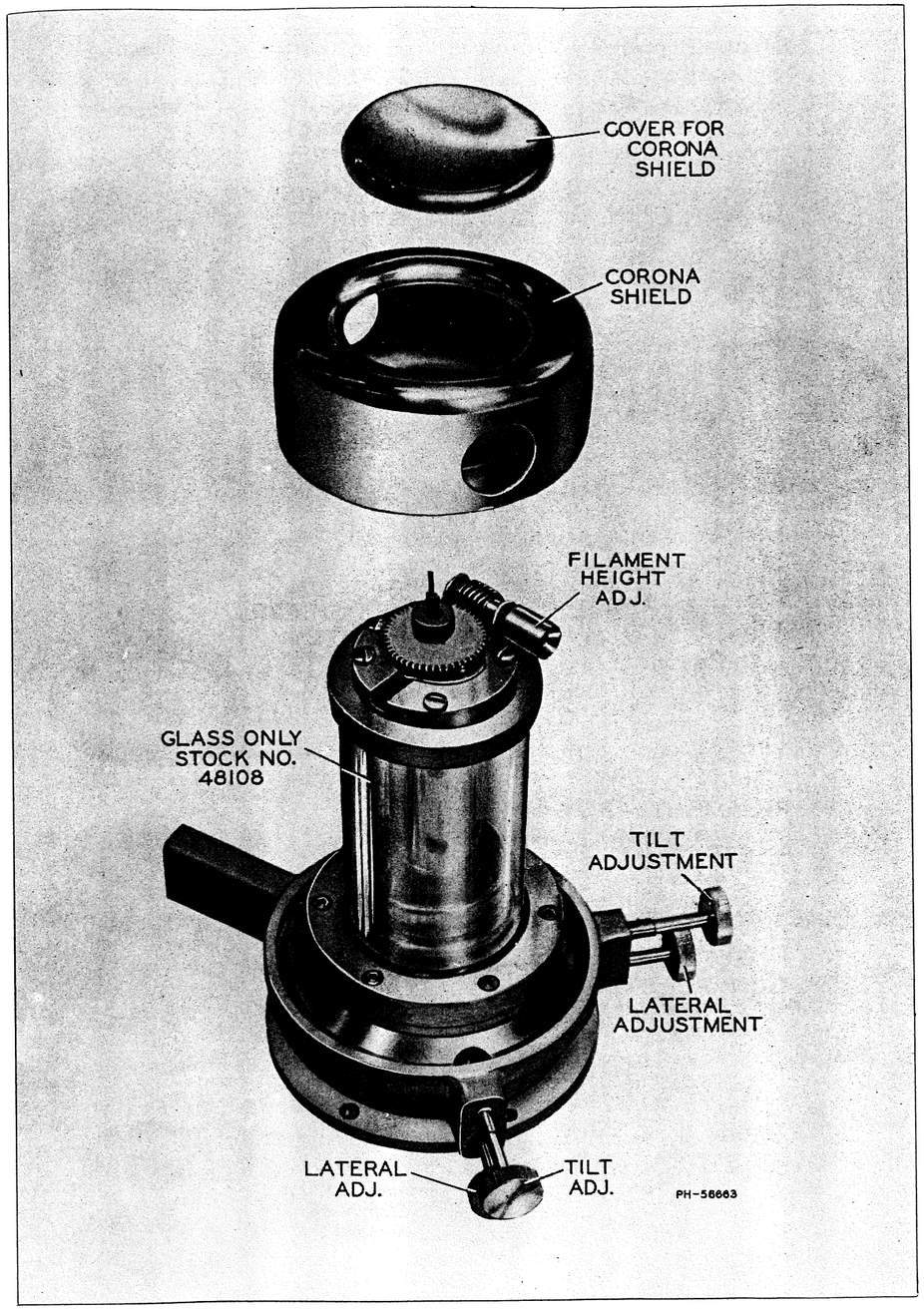


Figure 19—*Electron Gun with Base and Corona Shields*

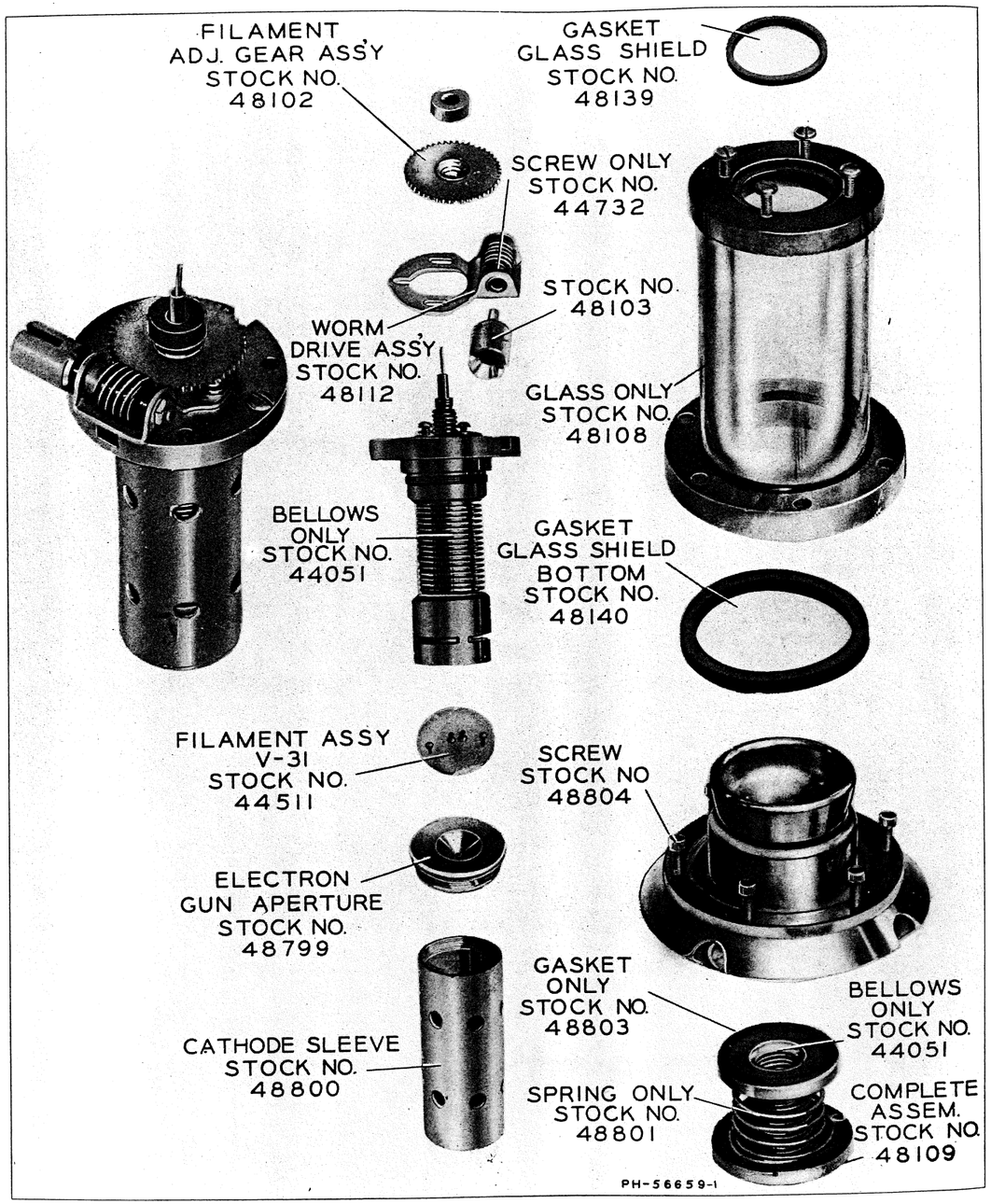


Figure 20—Electron Gun Assembly and Parts

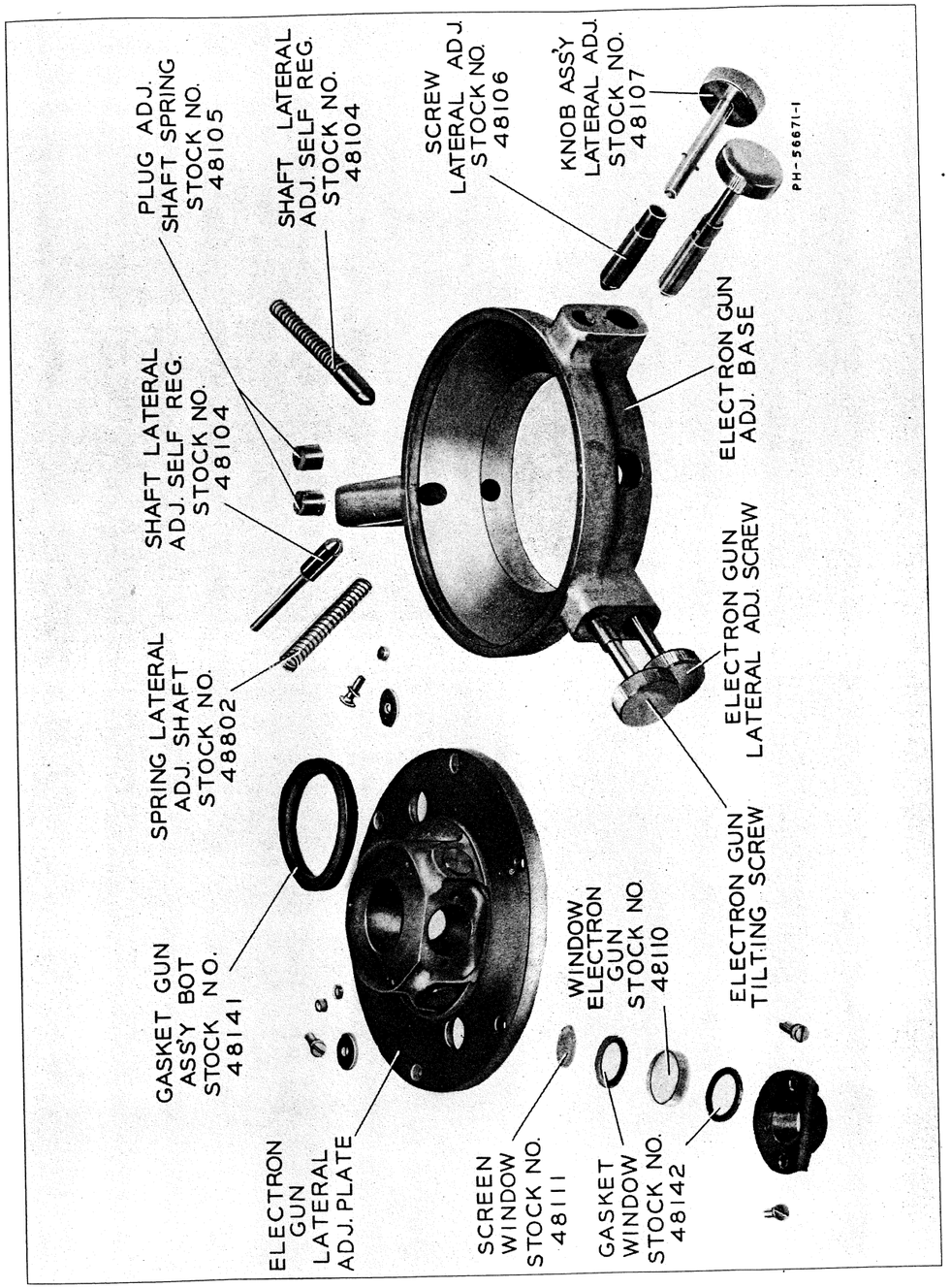


Figure 21—Electron Gun Base Disassembled

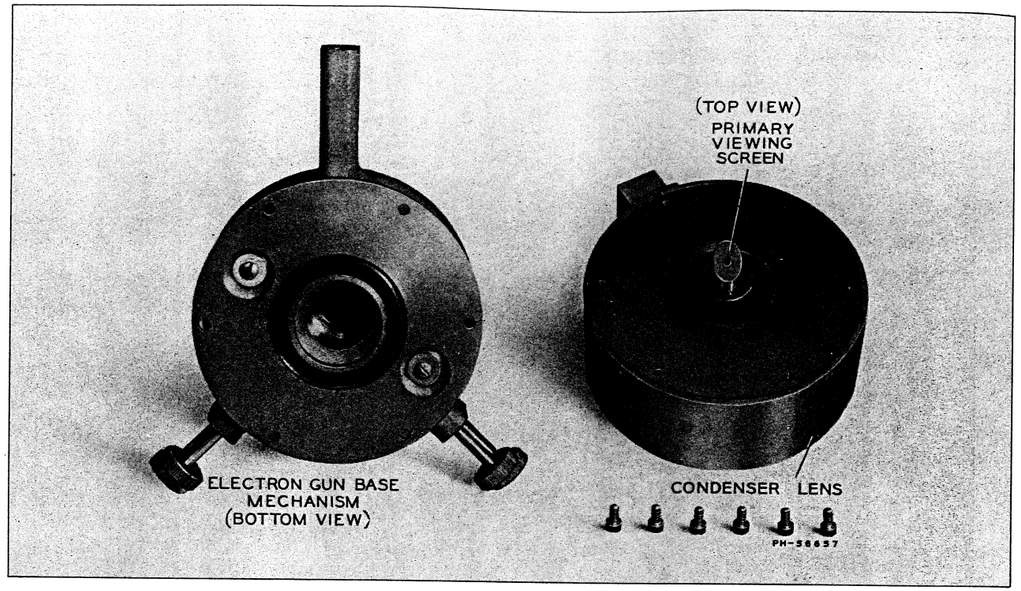


Figure 22—Electron Gun Base and Condenser Lens

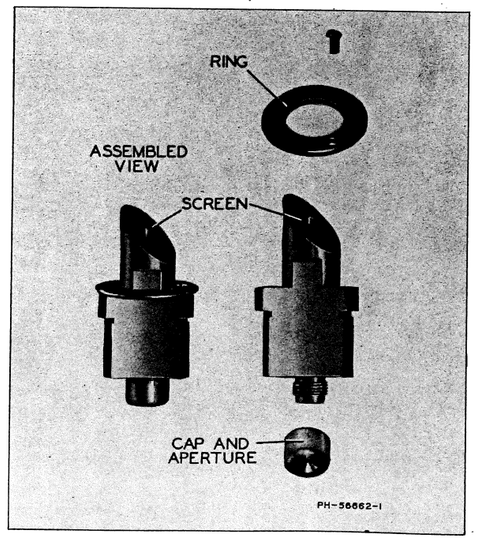


Figure 23—Primary Viewing Screen and Condenser Aperture

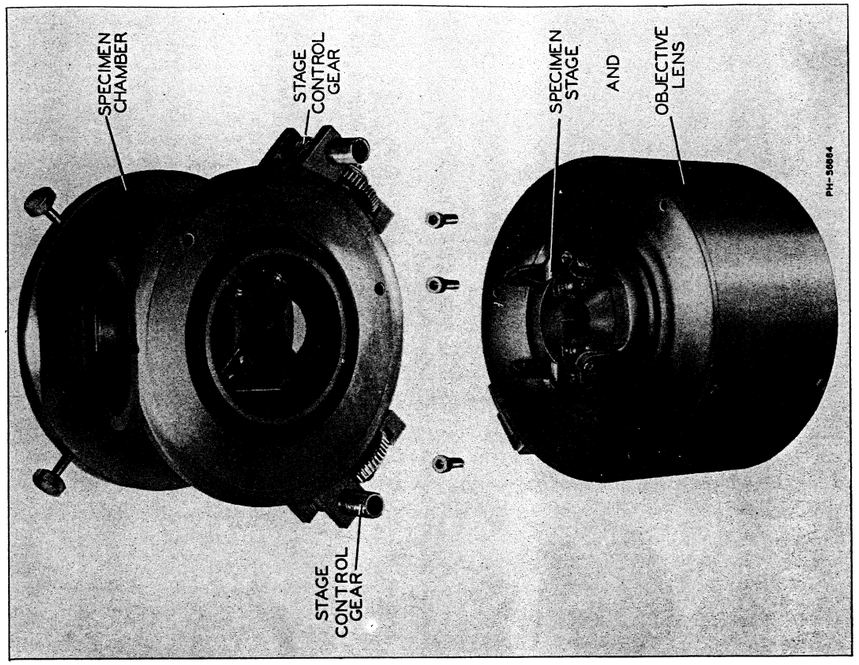


Figure 25—Specimen Chamber, Specimen Stage and Objective Lens

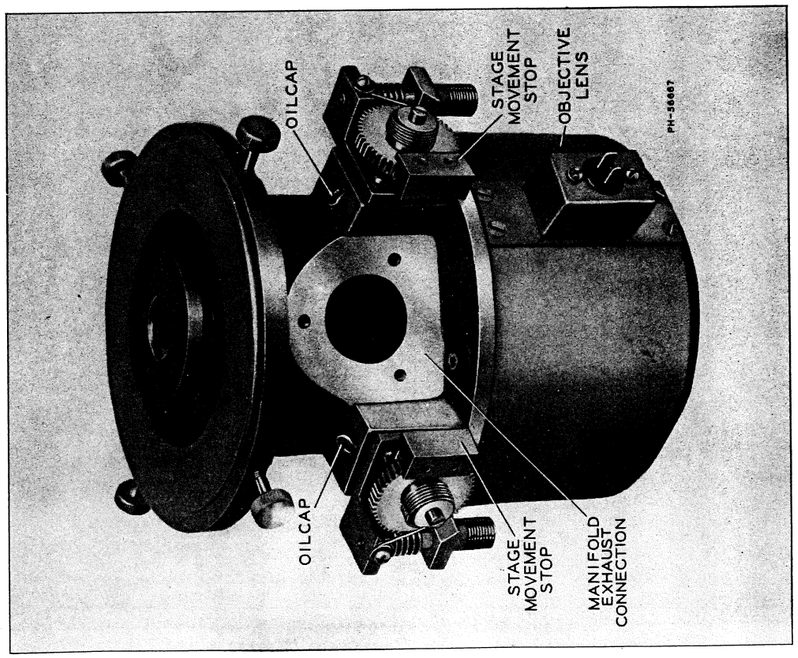


Figure 24—Specimen Chamber and Objective Lens, Rear View

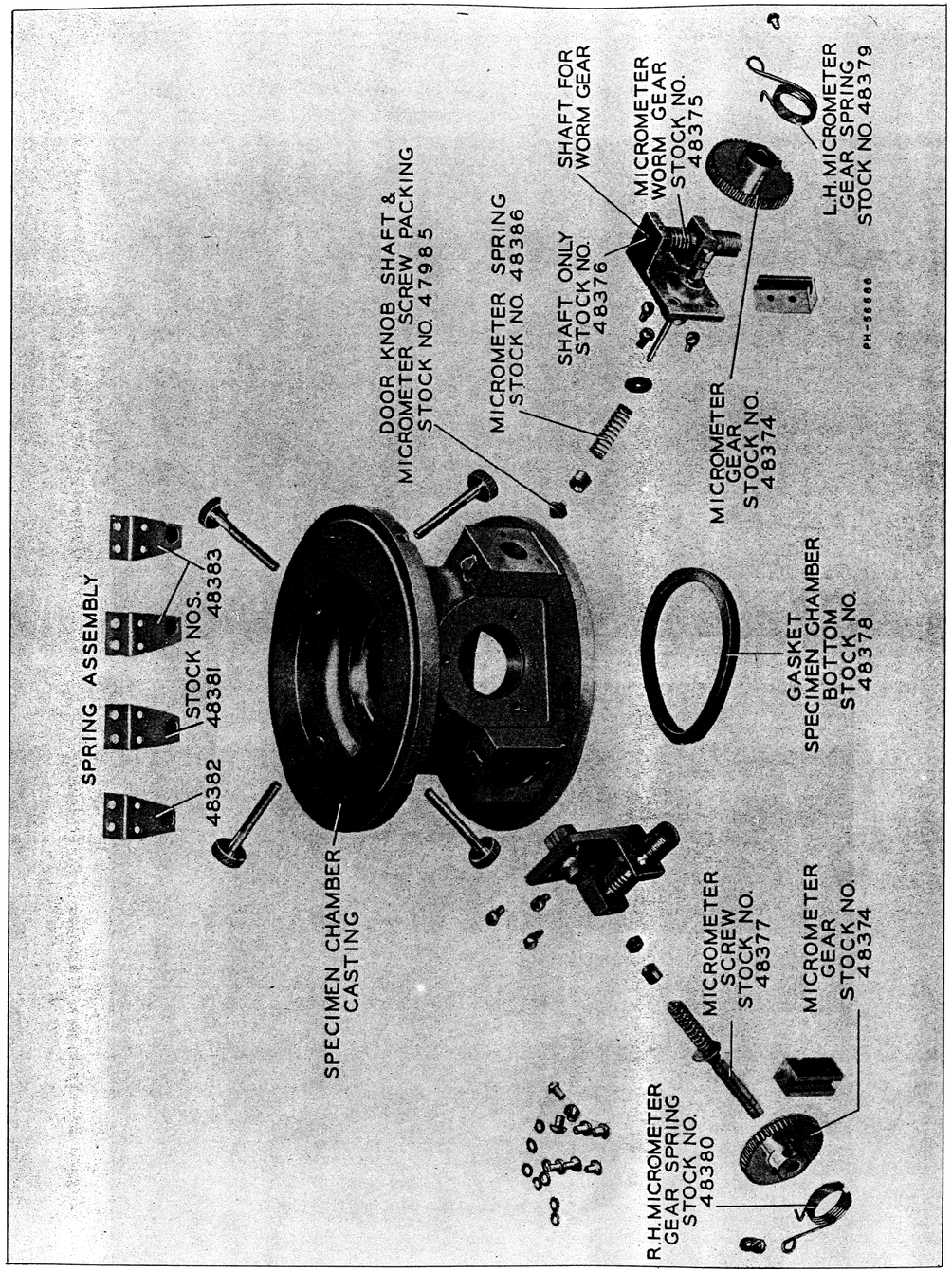


Figure 26—Specimen Chamber, Disassembled, Rear View

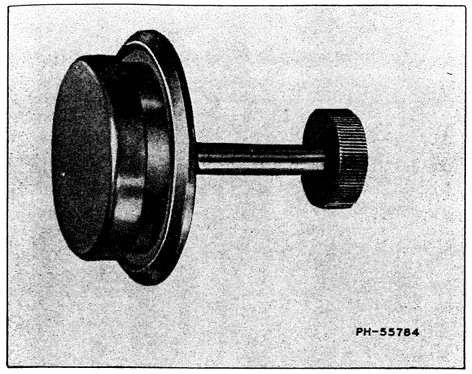


Figure 27—Standard Specimen Chamber Door

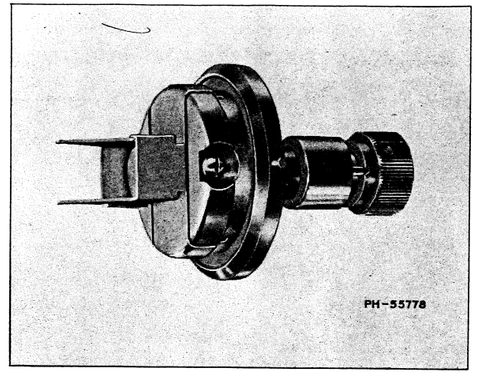


Figure 28—Specimen Chamber Stereo Door in Neutral Position, Bottom View

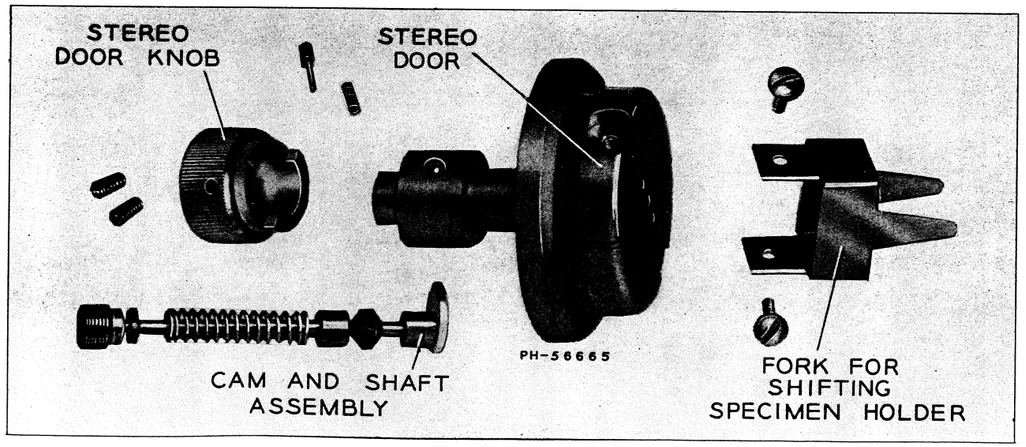


Figure 29—Stereo Door, Disassembled

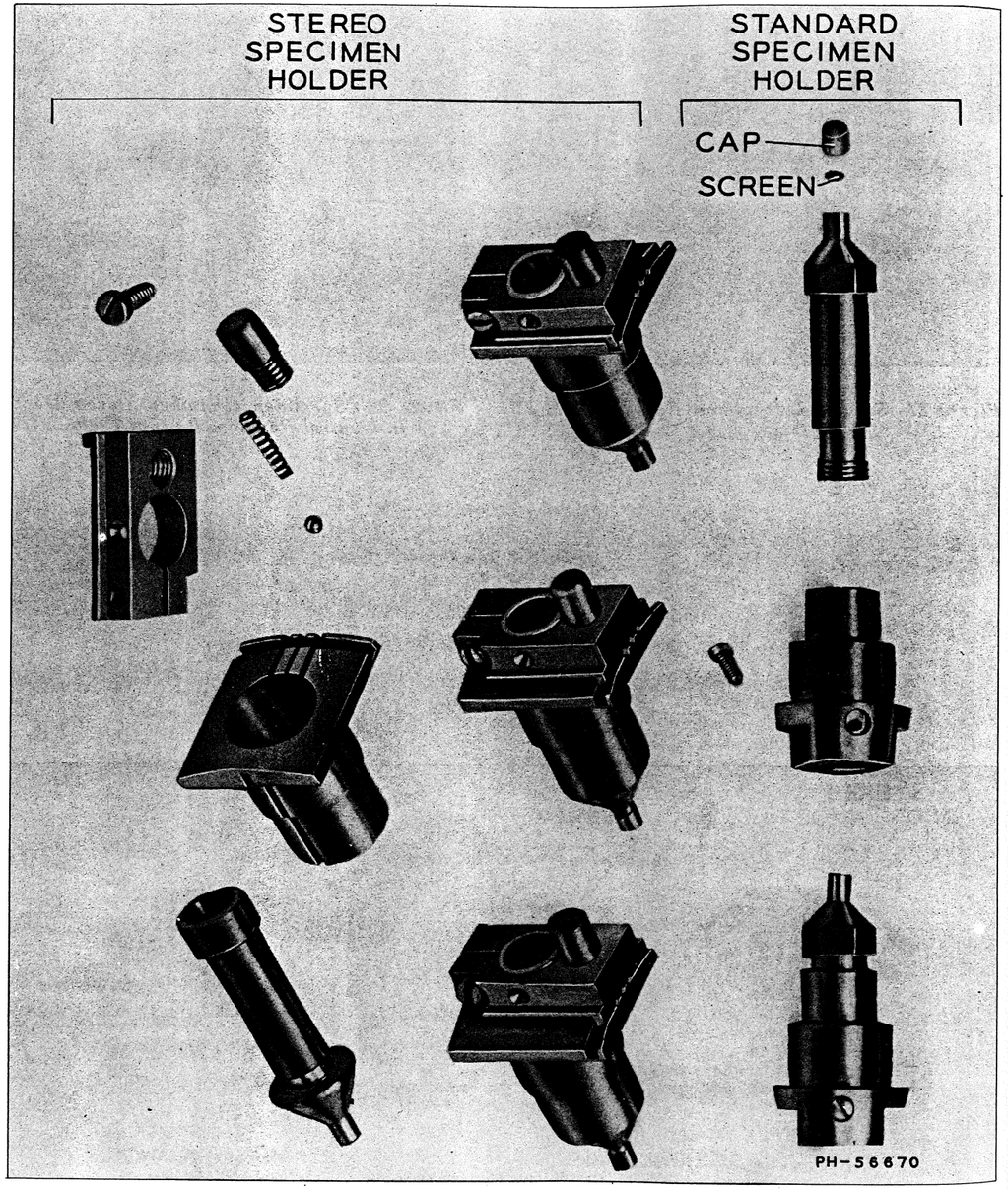


Figure 30—Specimen Holders and Parts

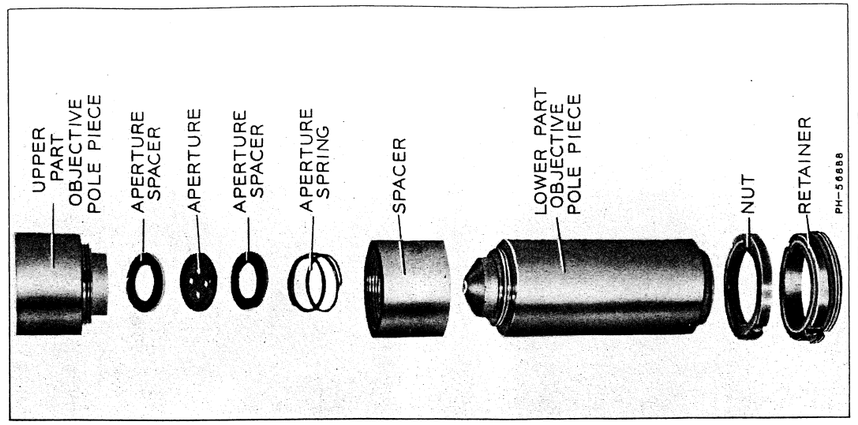


Figure 33—Objective Pole Piece Disassembled

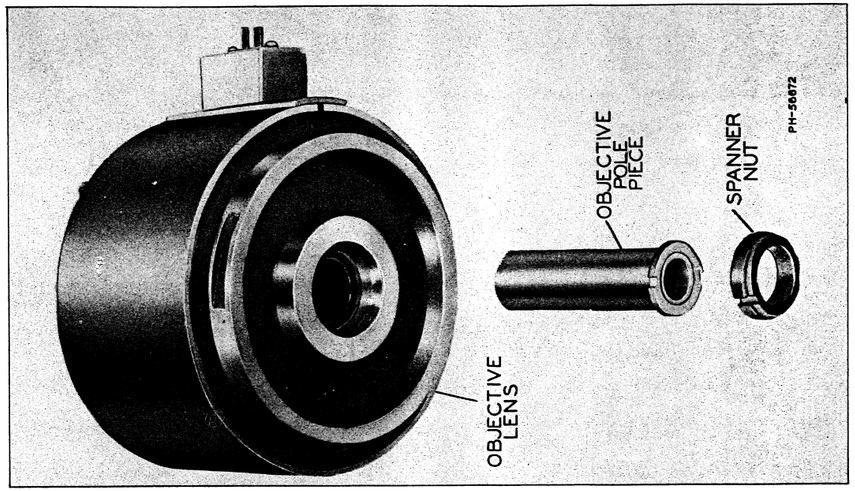


Figure 32—Objective Lens and Pole Piece, Bottom View

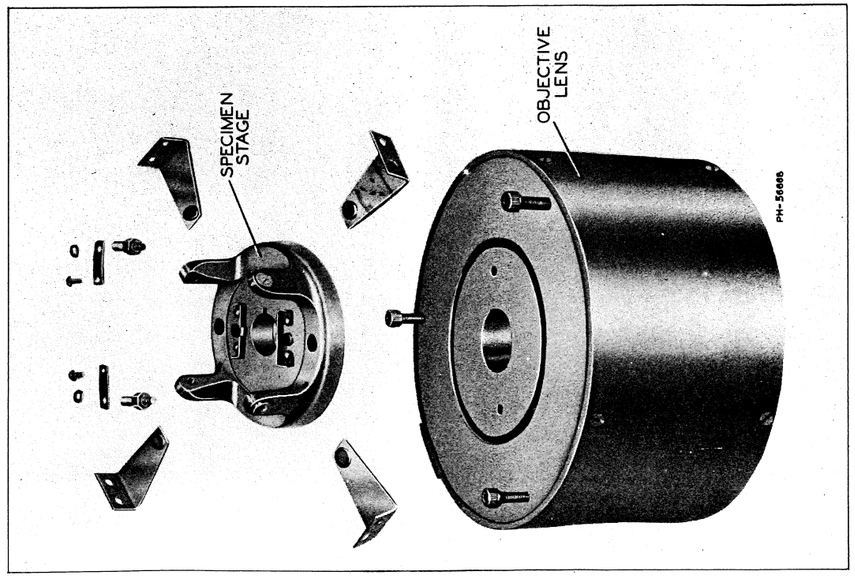


Figure 31—Specimen Stage, Disassembled, and Objective Lens

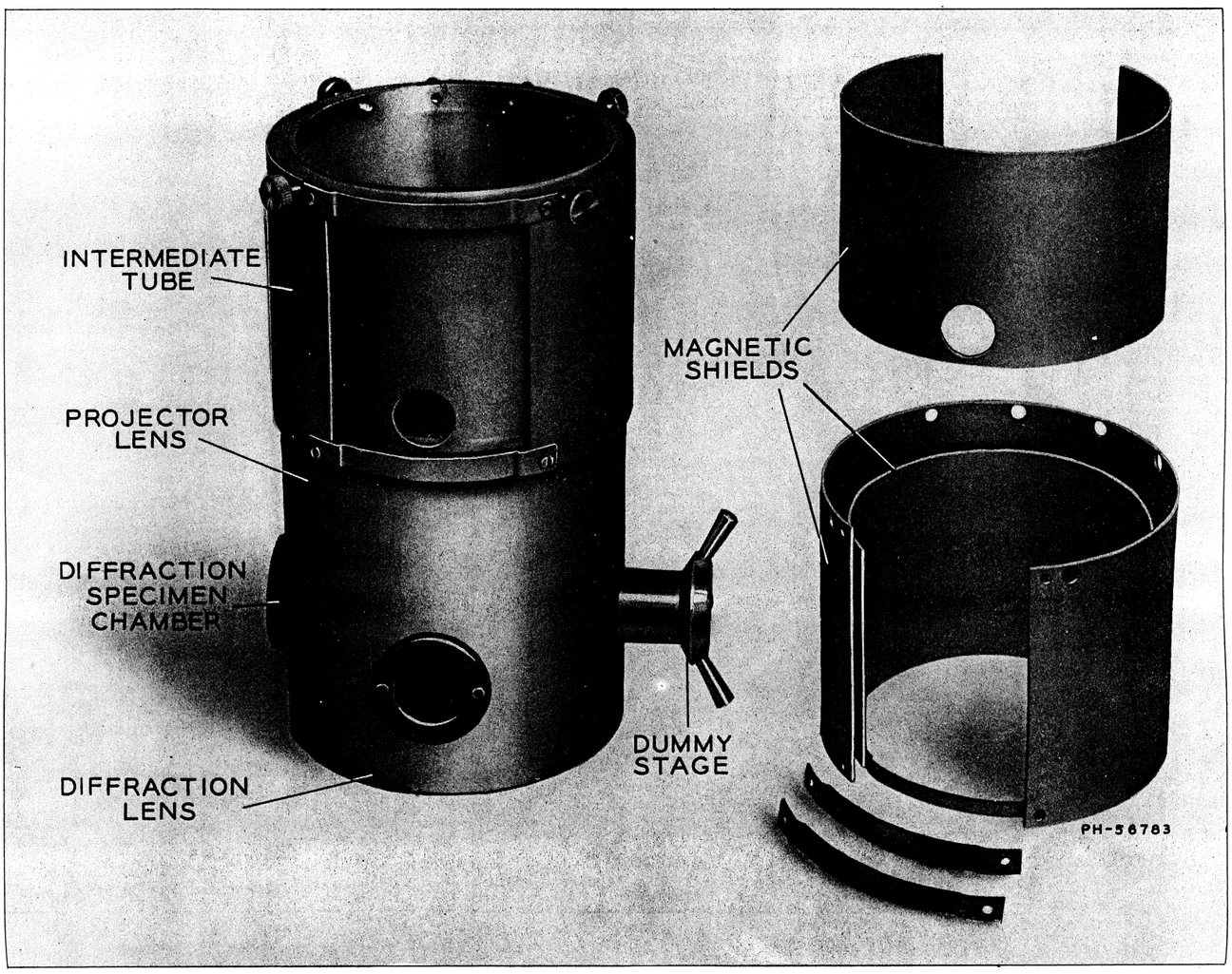


Figure 34—Intermediate Tube and Projector Lens

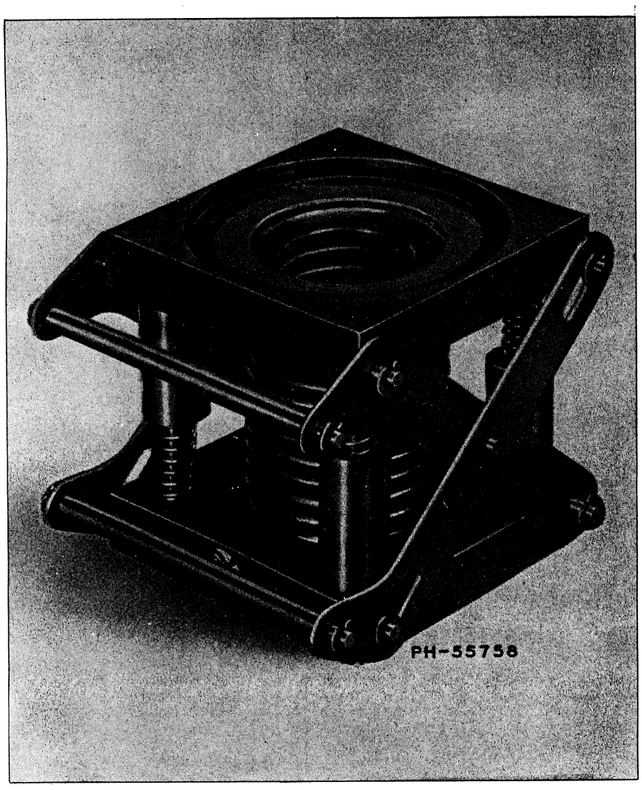


Figure 35—Bellows for Intermediate Tube

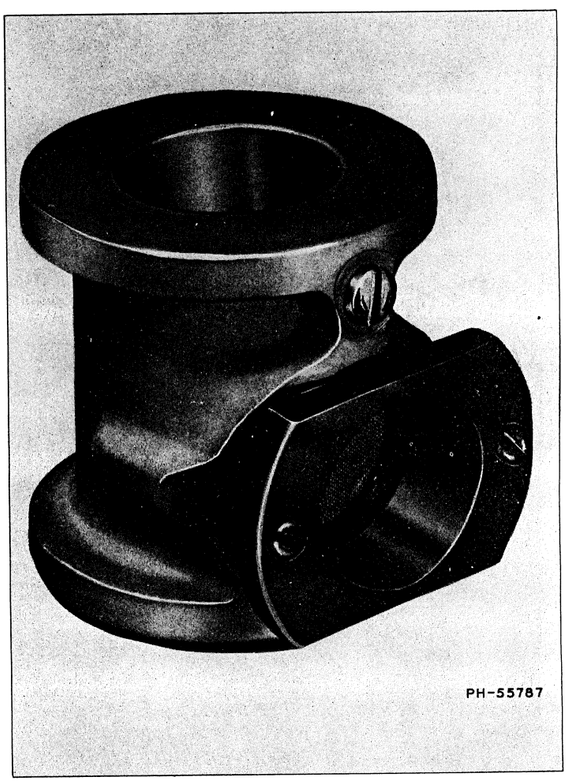


Figure 36—Intermediate Tube Casting

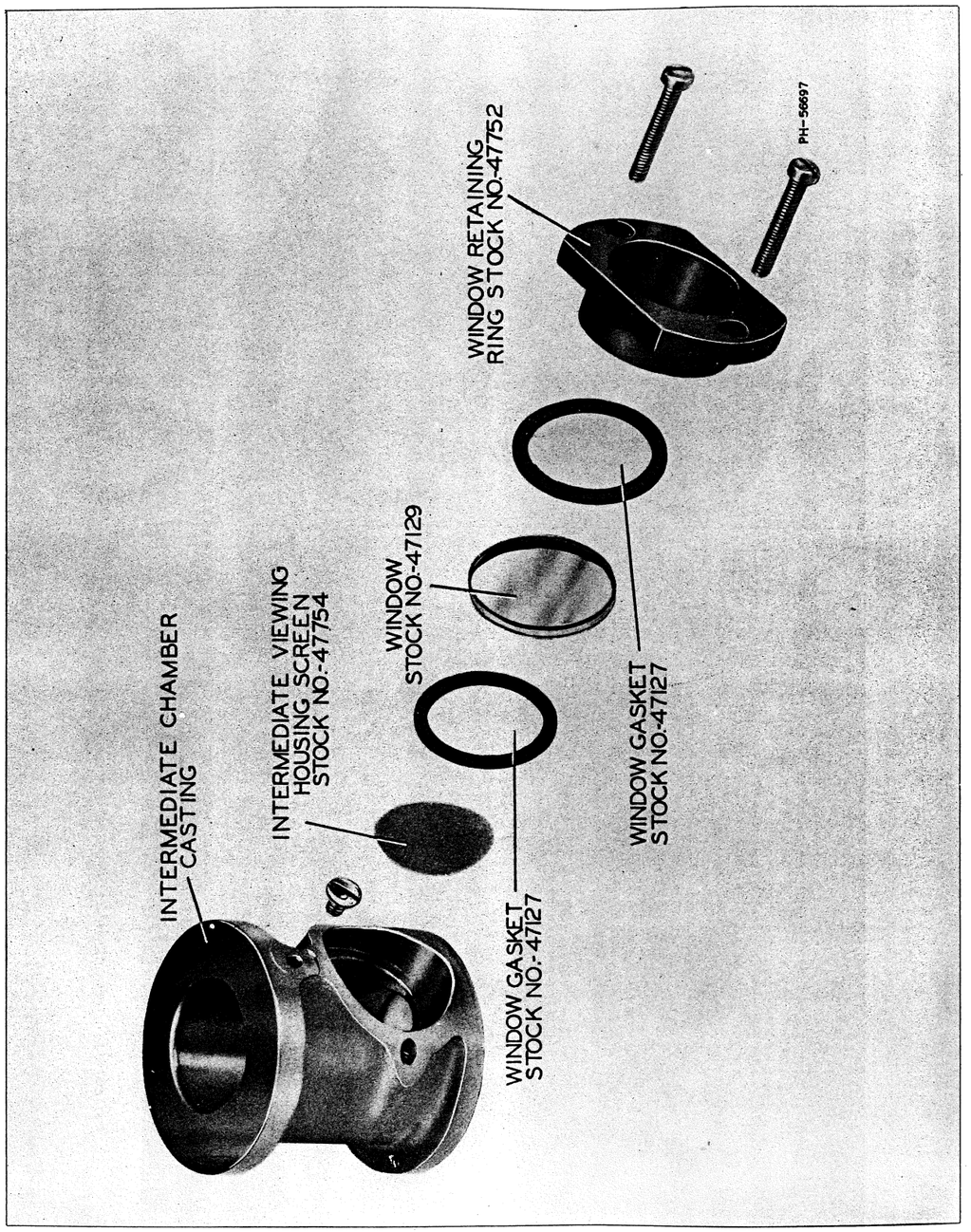


Figure 37—Intermediate Chamber, Disassembled

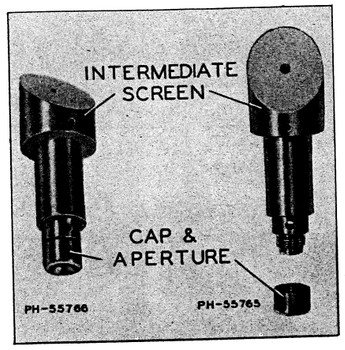


Figure 38—Intermediate View Screen and Aperture

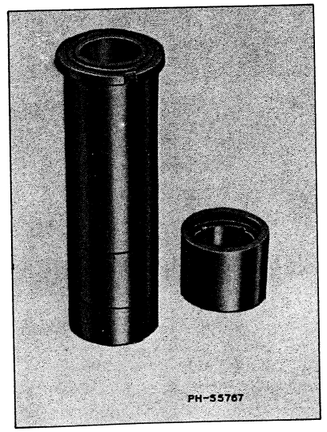


Figure 39—Projector Pole Piece

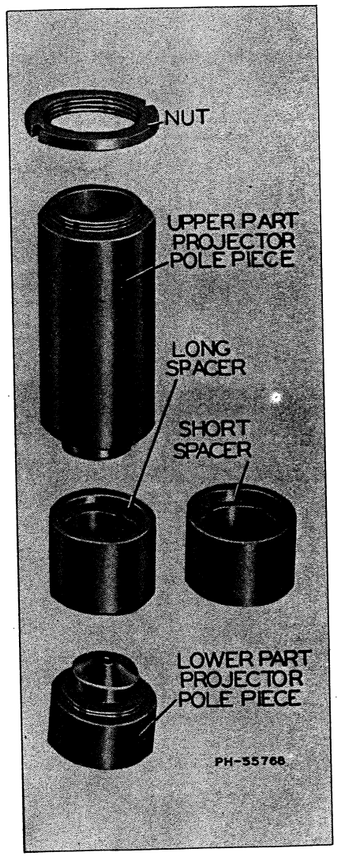


Figure 40—Projector Pole Piece, Disassembled

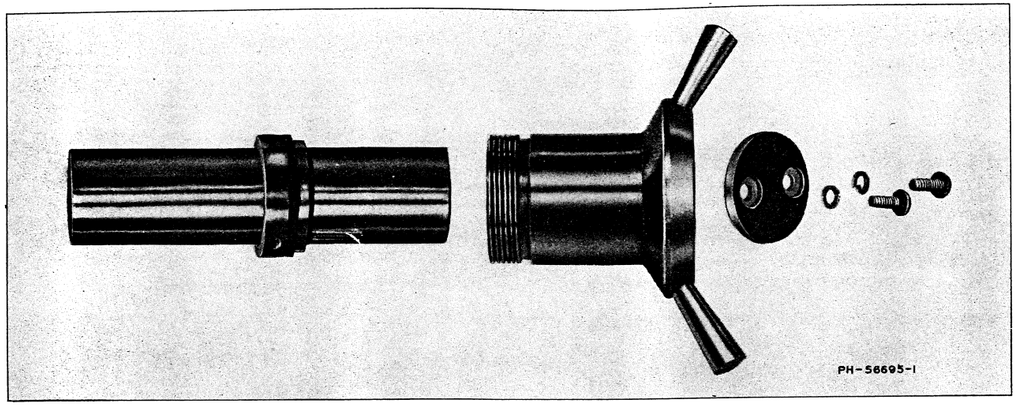


Figure 41—Dummy Diffraction Stage

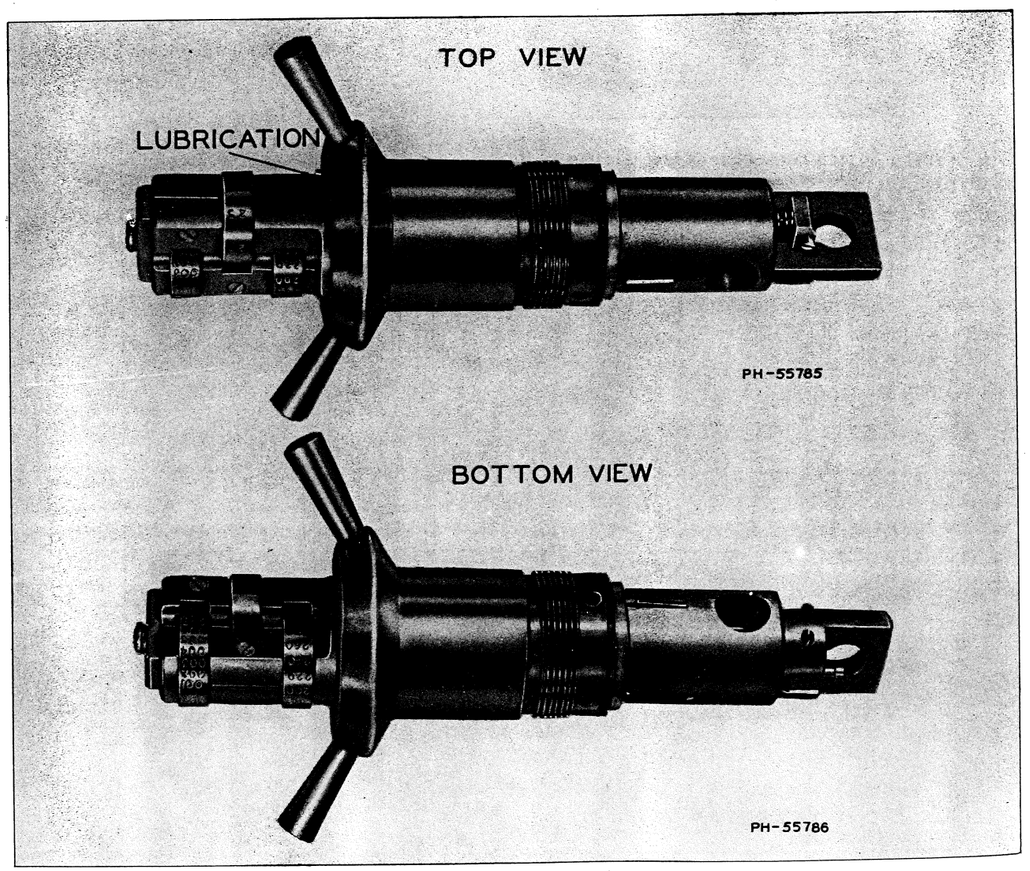


Figure 42—Diffraction Stage

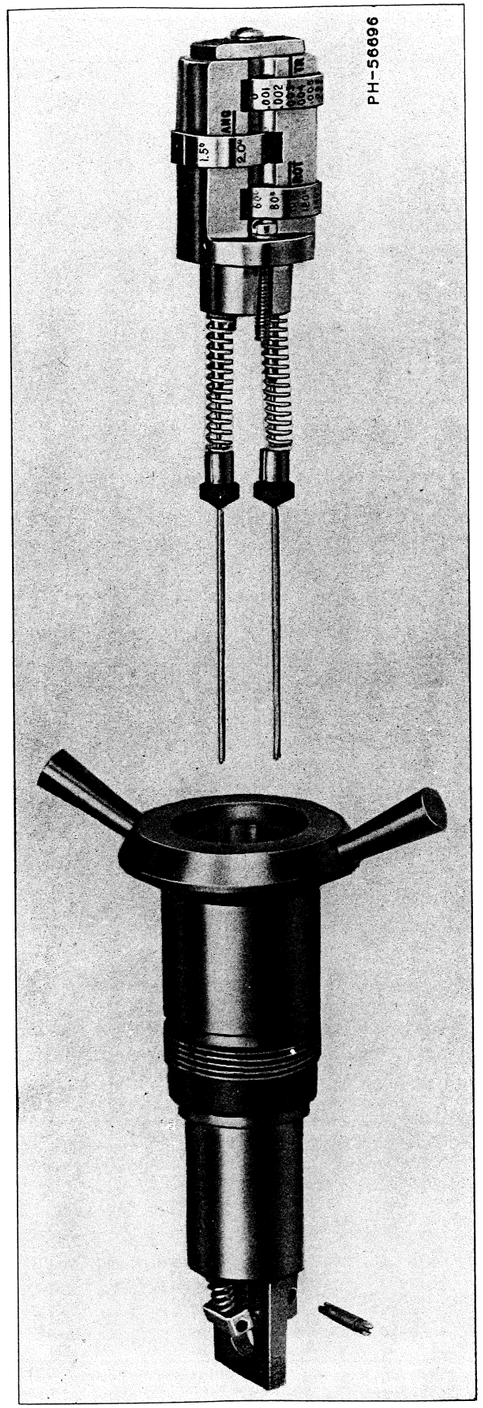


Figure 43—Diffraction Stage, Partly Disassembled

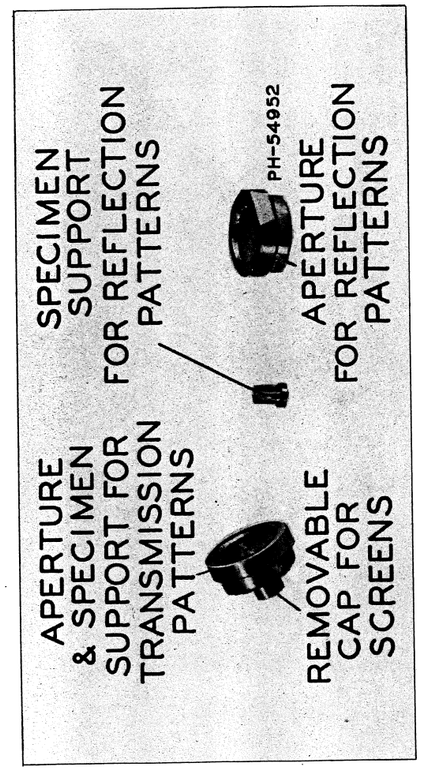


Figure 44—Diffraction Unit, Apertures and Specimen Supports

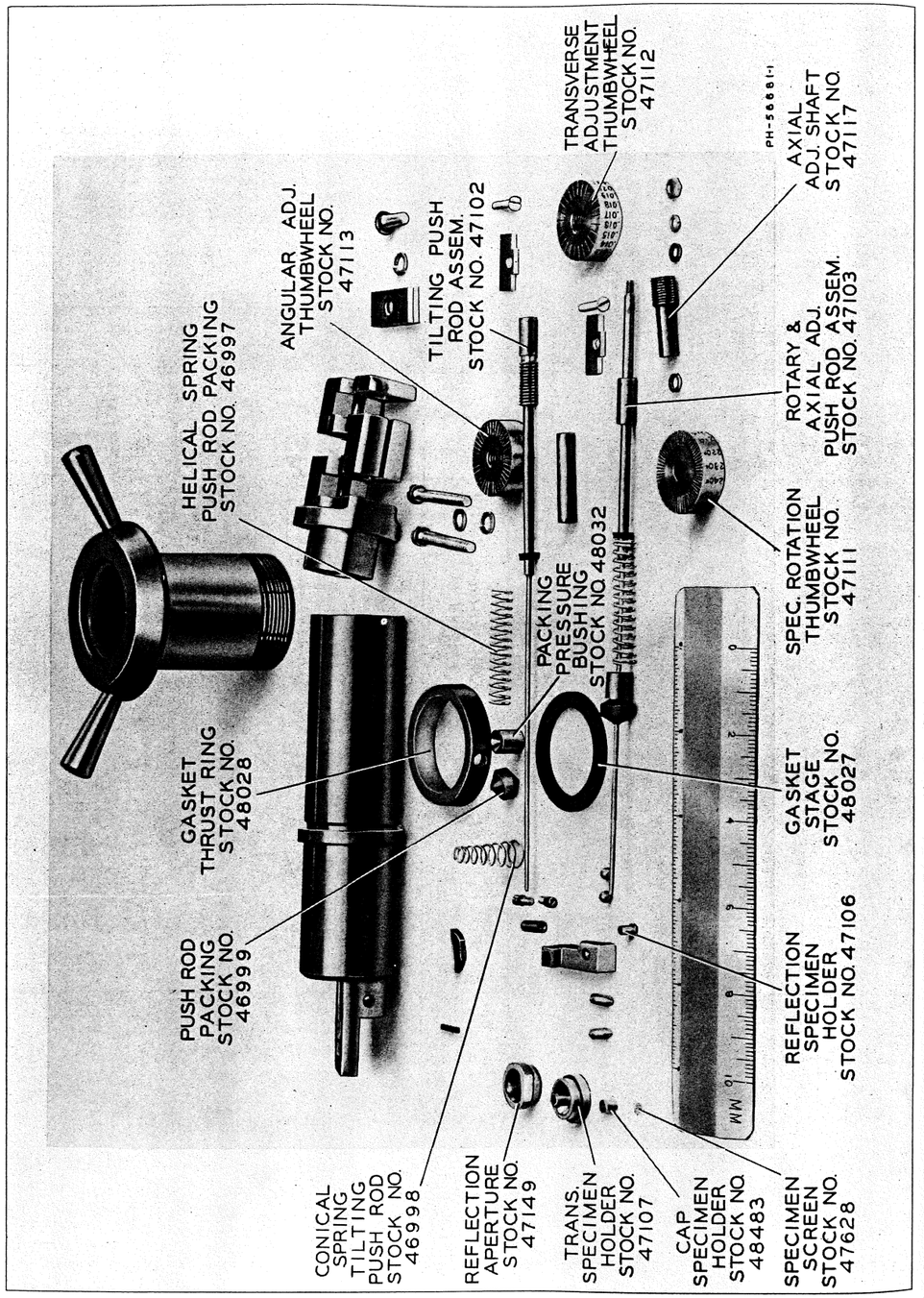
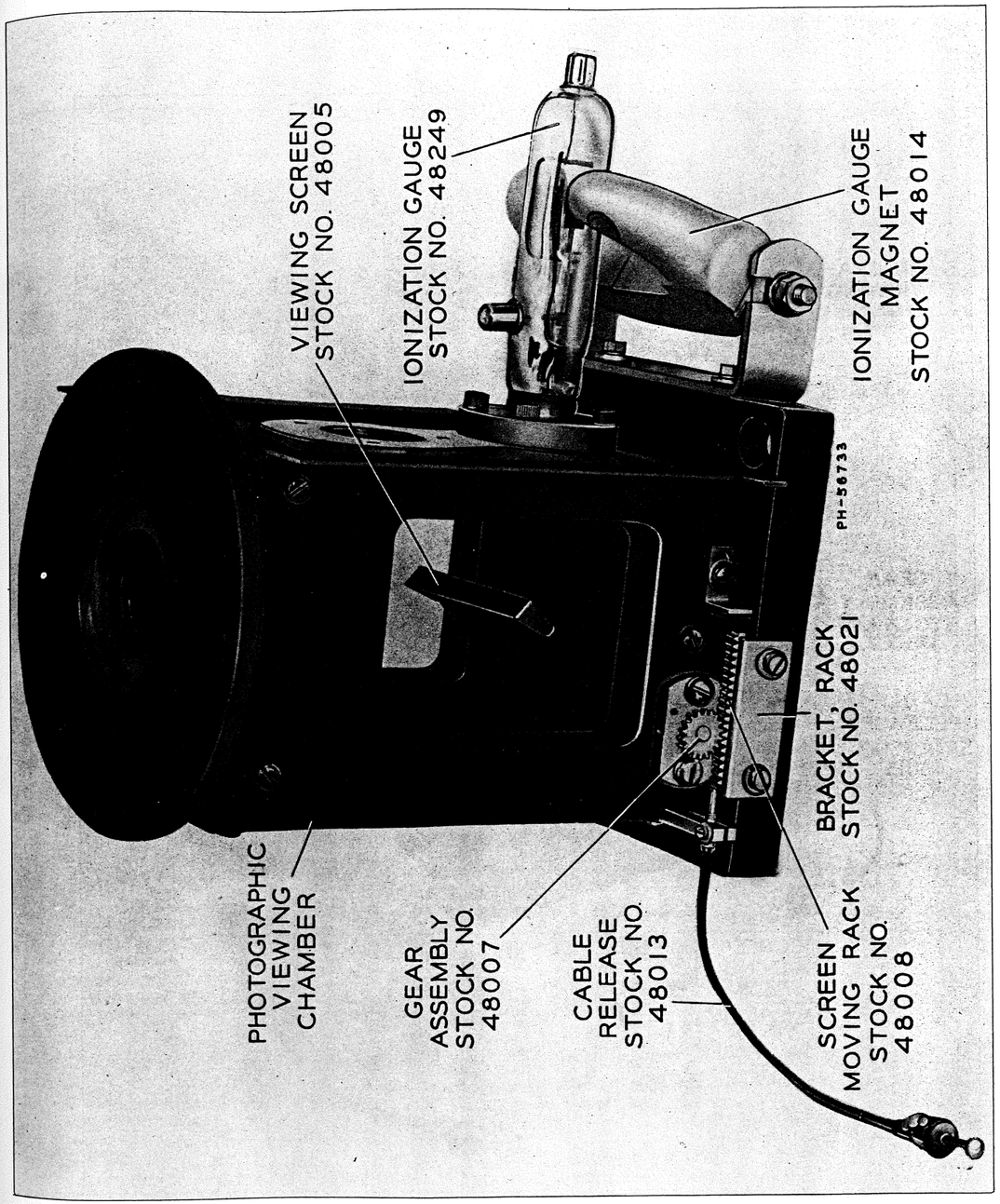


Figure 45—Diffraction Stage, Disassembled



NOTE: Ionization gauge shown is an early type, now superseded by Stock No. 51165, as shown in Figure 46B.

Figure 46A—Final Viewing Chamber, Right Side View, Electron Microscope, Types EMU-1 and EMU-2

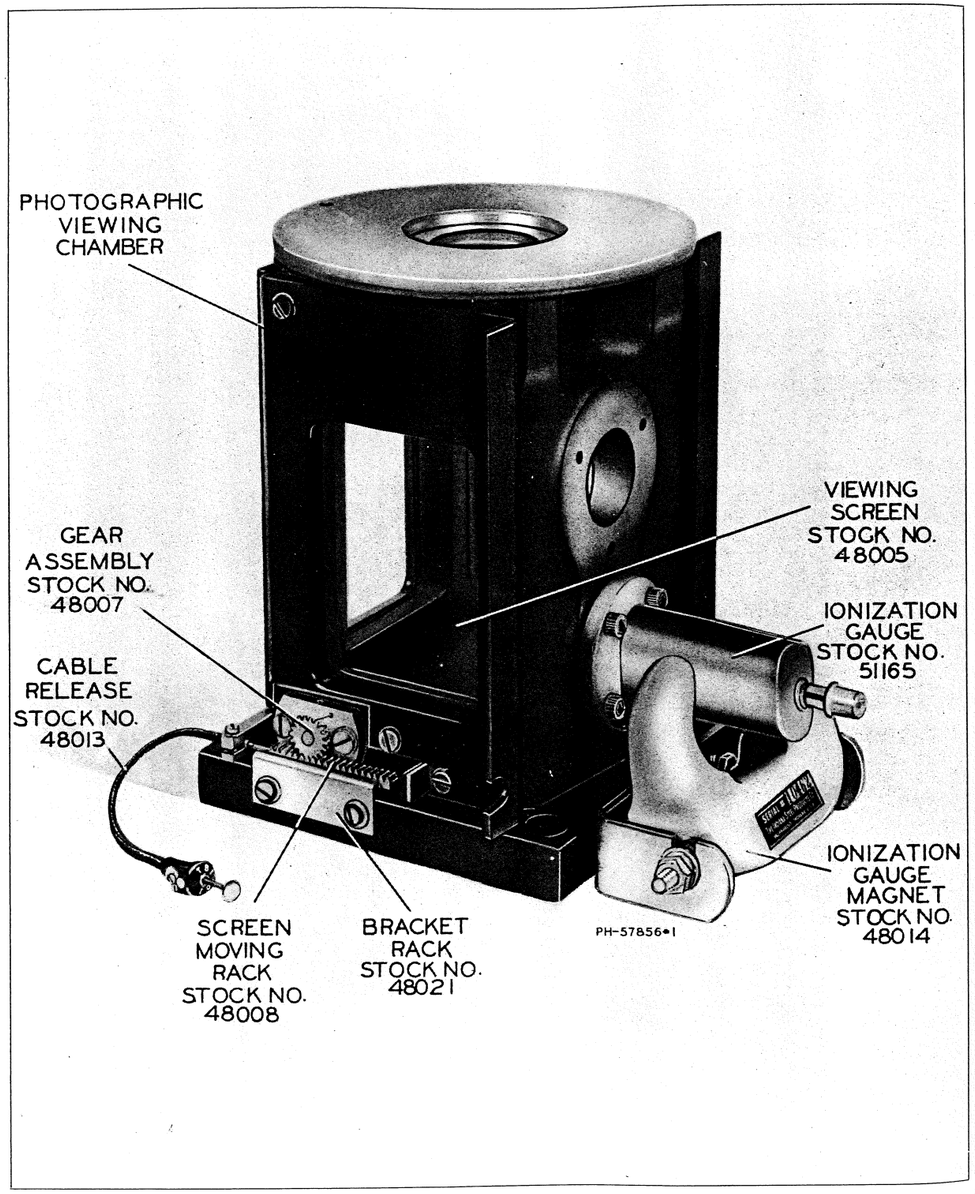
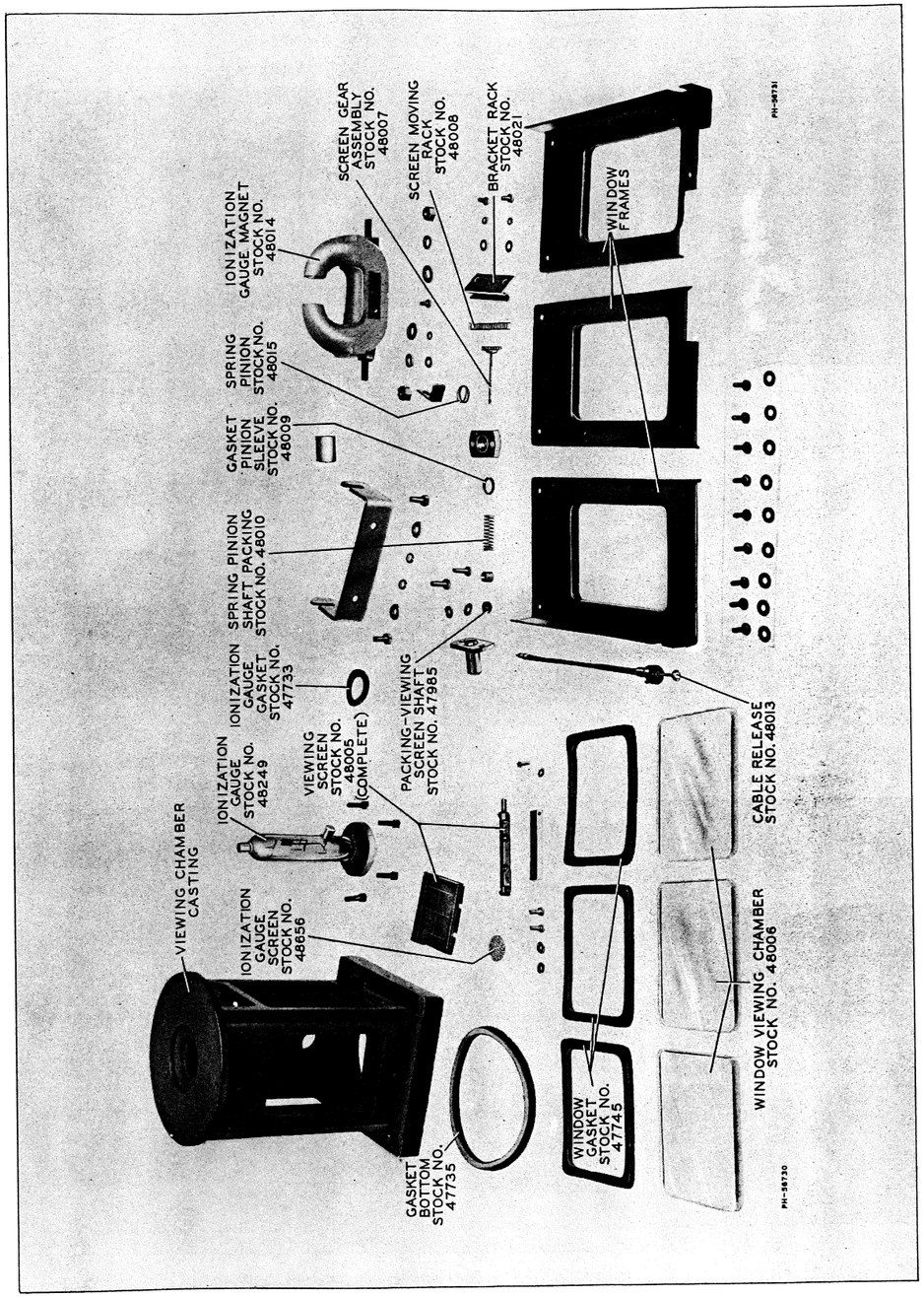


Figure 46B—Final Viewing Chamber, Right Side View, Electron Microscope, Type EMU-2A



NOTE: Ionization gauge shown is an early type, now superseded by Stock No. 51165, as shown in Figure 46B. Gasket Stock No. 47733 is, accordingly changed to Stock No. 53631.

Figure 47—Final Viewing Chamber, Disassembled

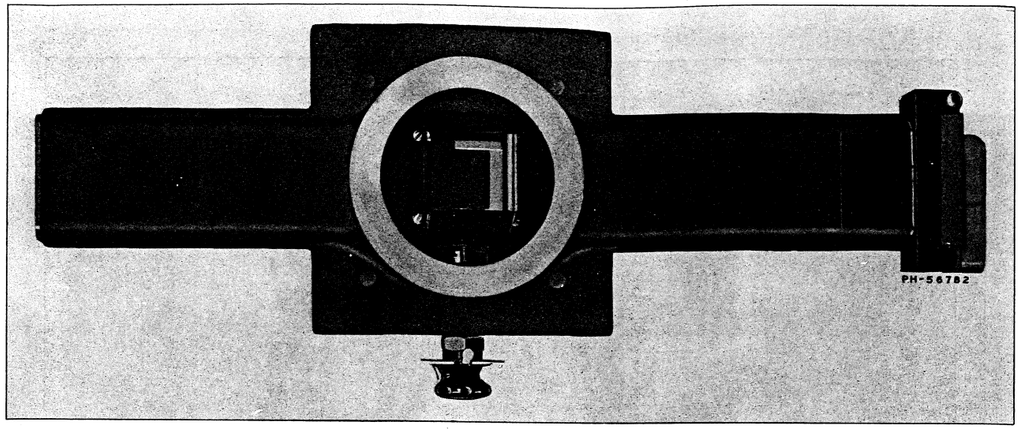


Figure 48—Photographic Chamber, Top View

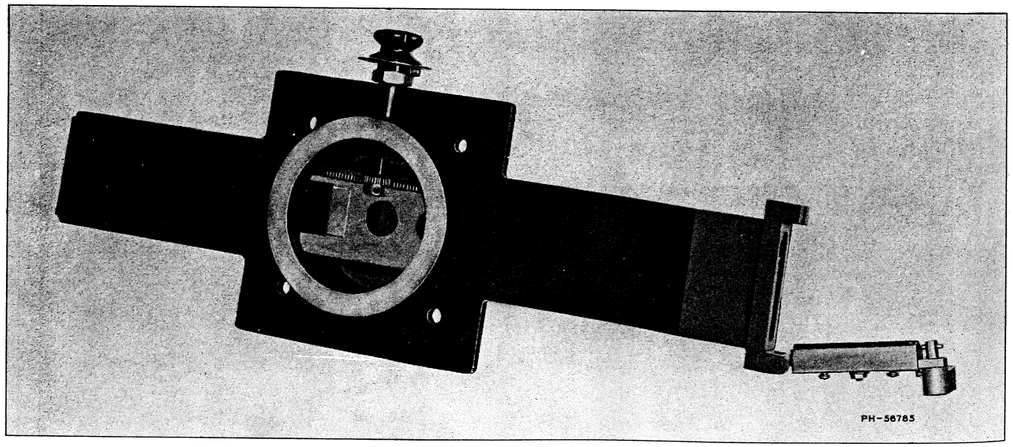


Figure 49—Photographic Chamber, Bottom View

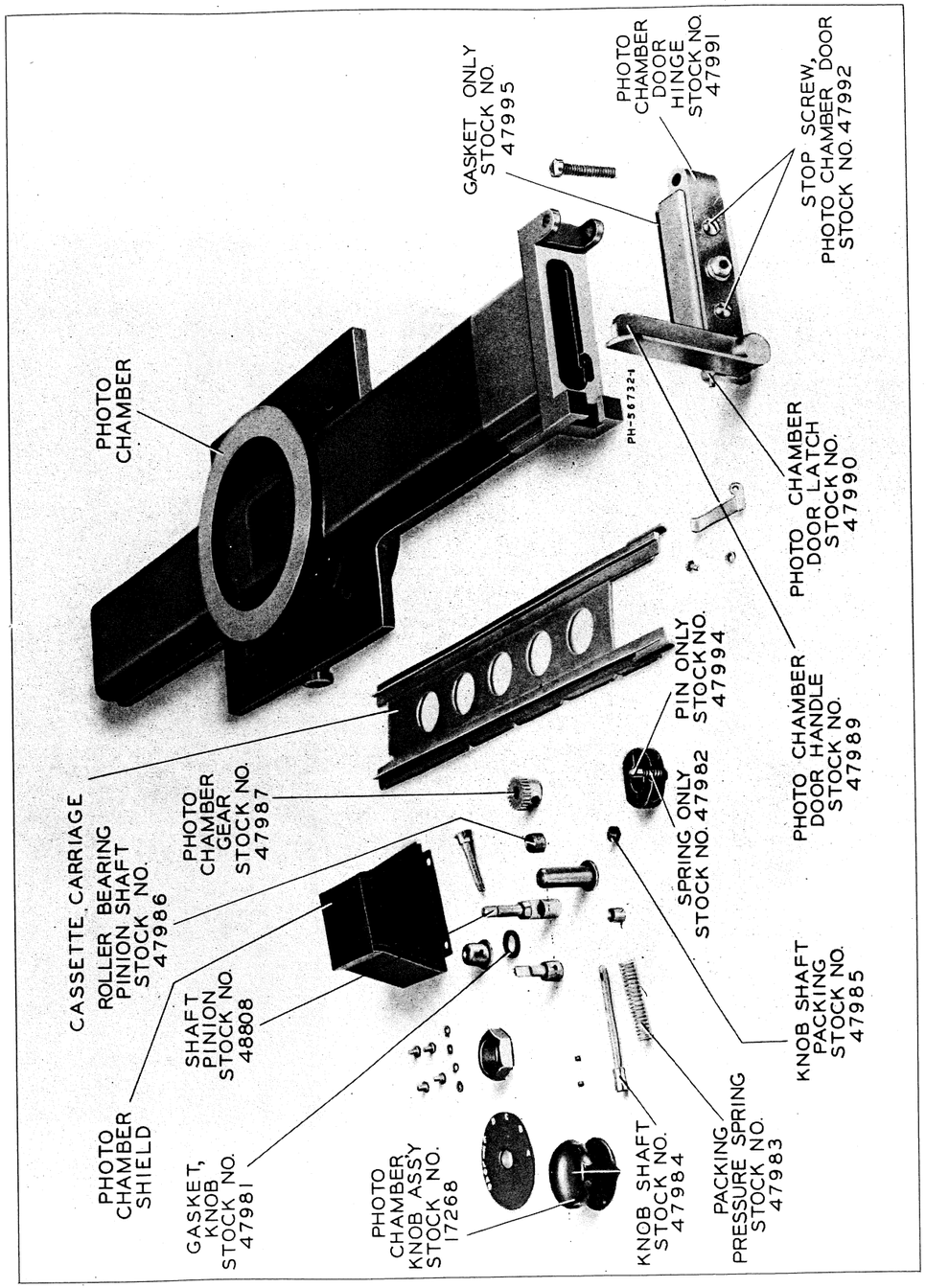


Figure 50—Photographic Chamber, Disassembled

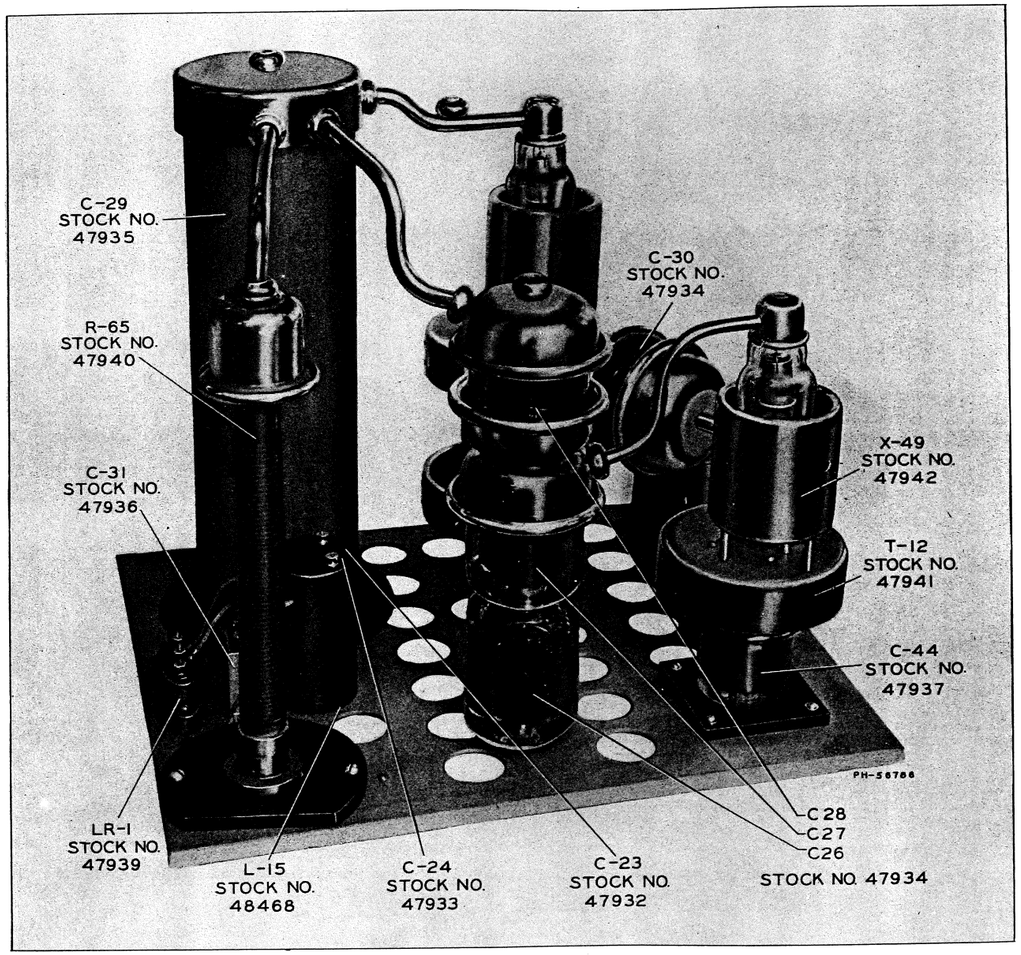


Figure 51—*High Voltage Unit, Front View*

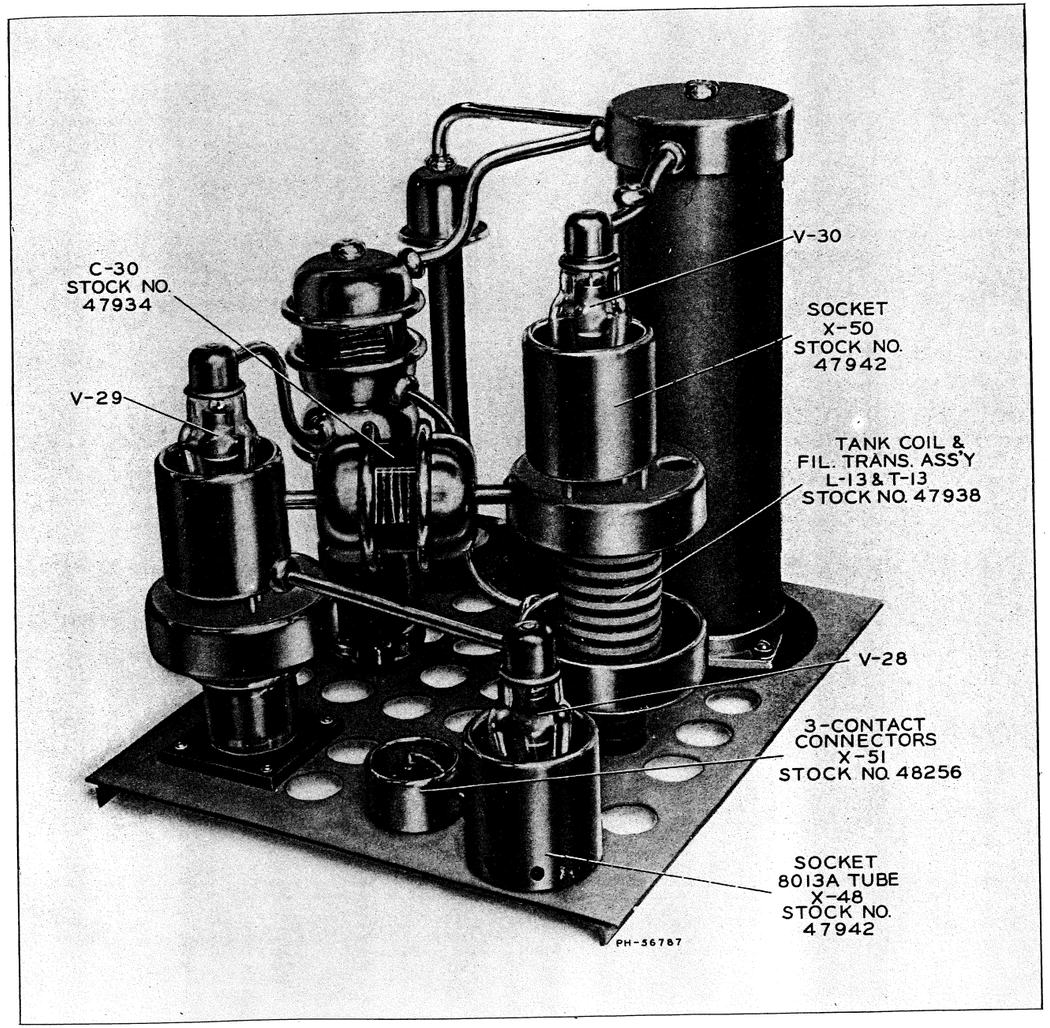


Figure 52—*High Voltage Unit, Rear Right Side View*

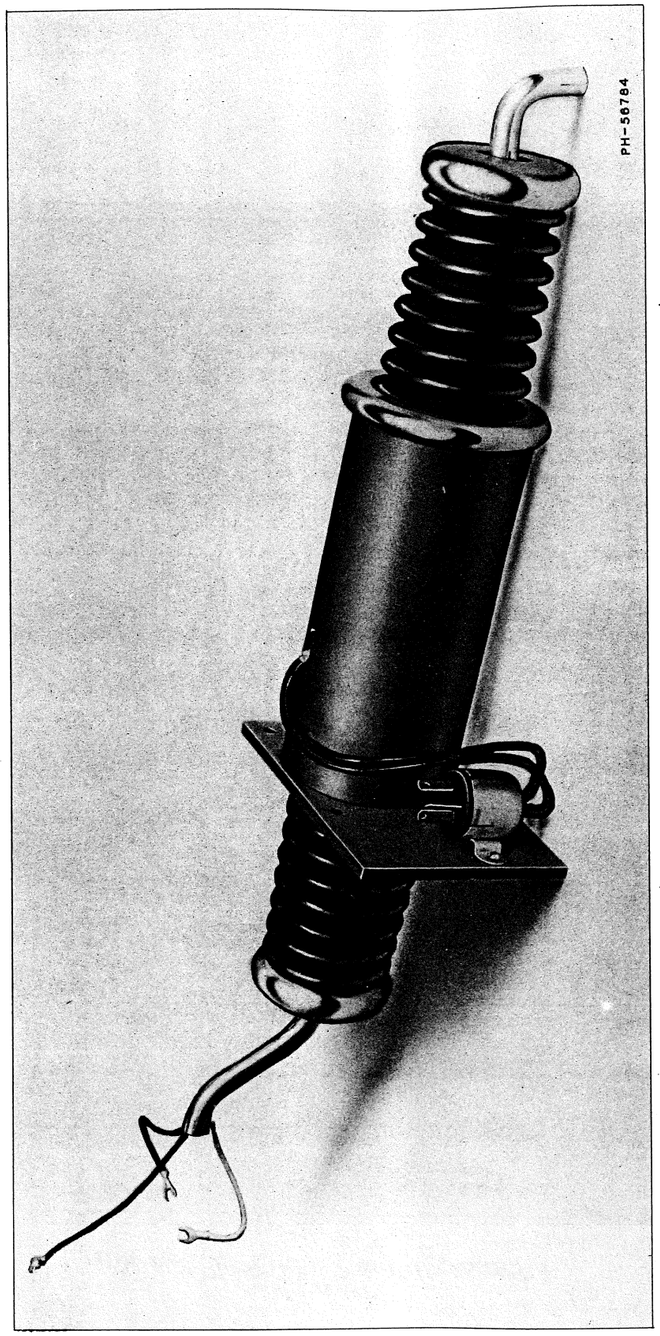


Figure 53—High Voltage Bushing

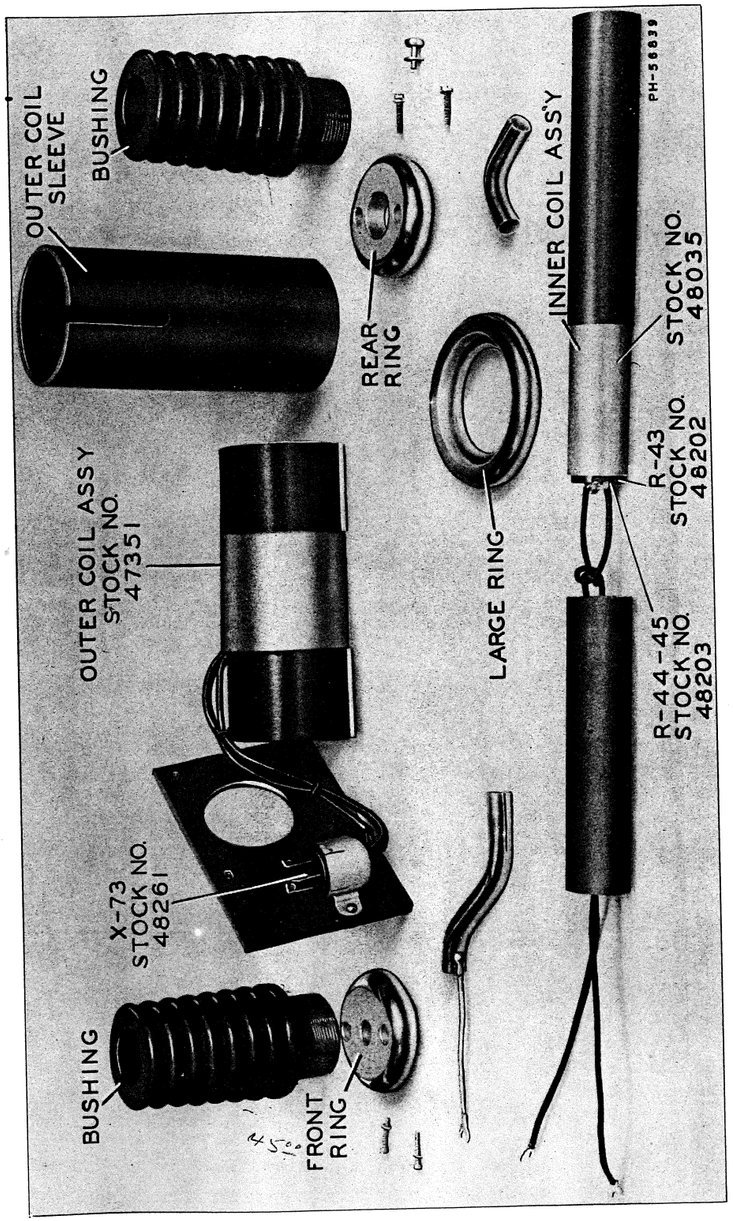


Figure 54—High Voltage Bushing, Disassembled

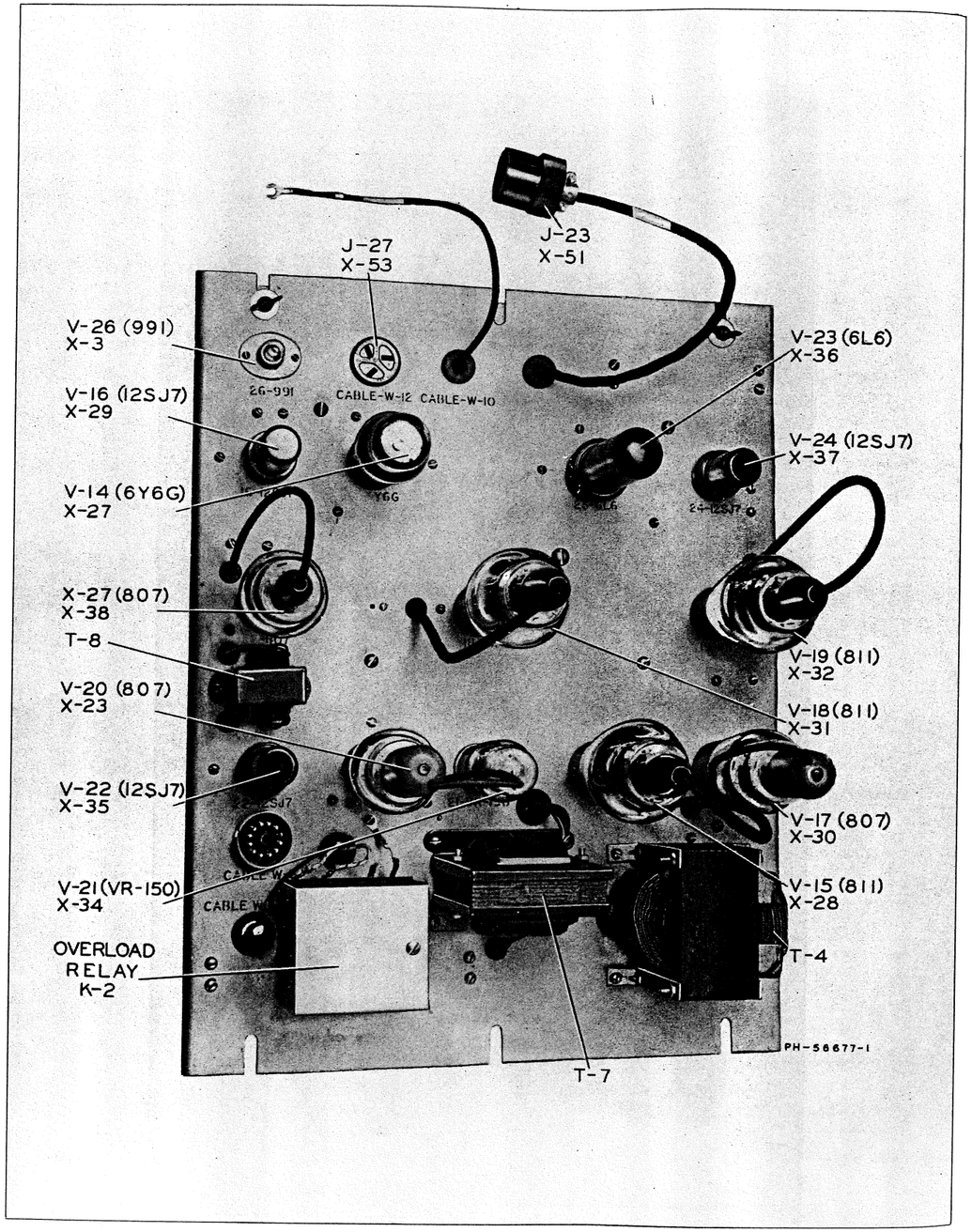


Figure 55—Top Chassis, Front View

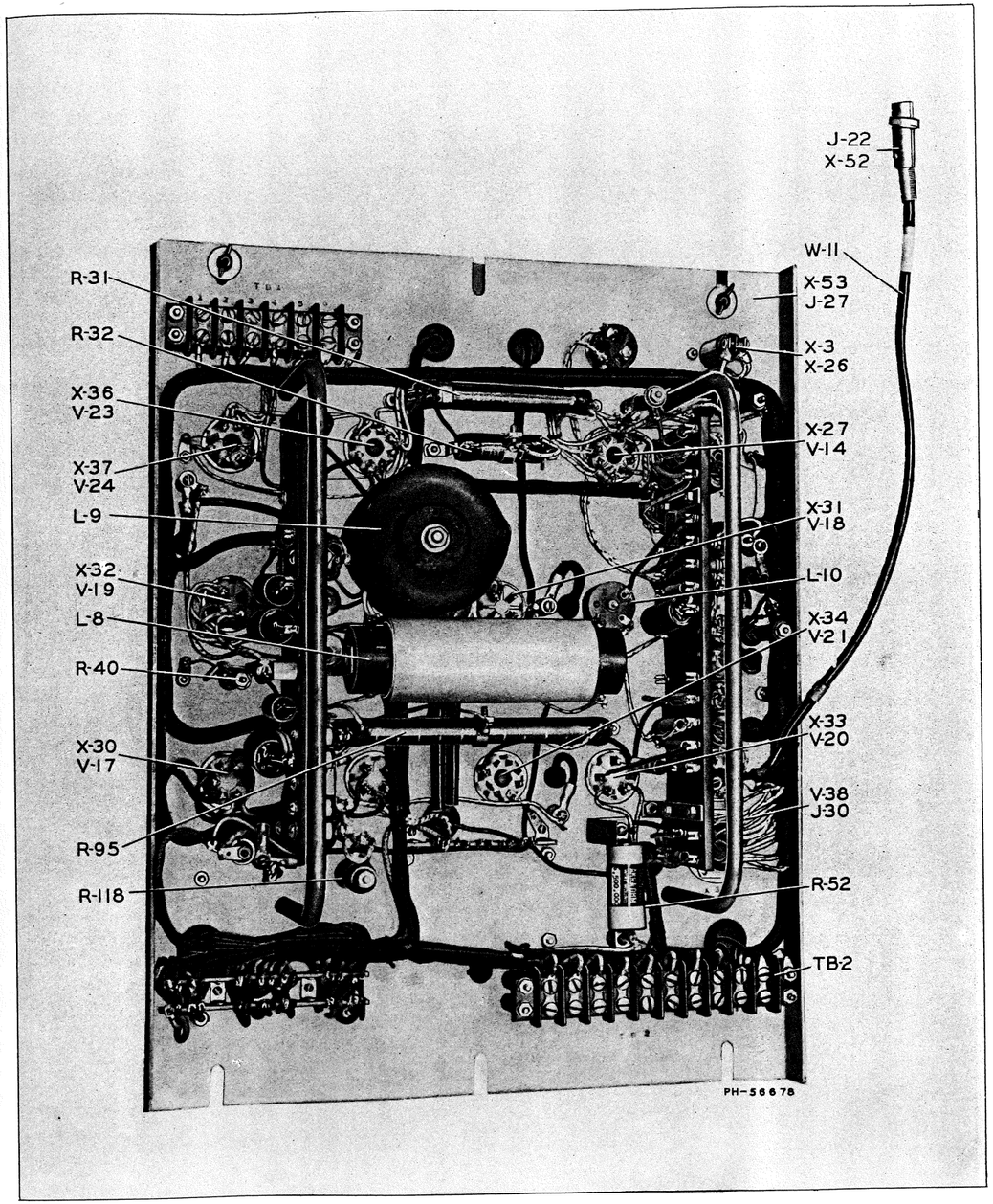


Figure 56—Top Chassis, Rear View

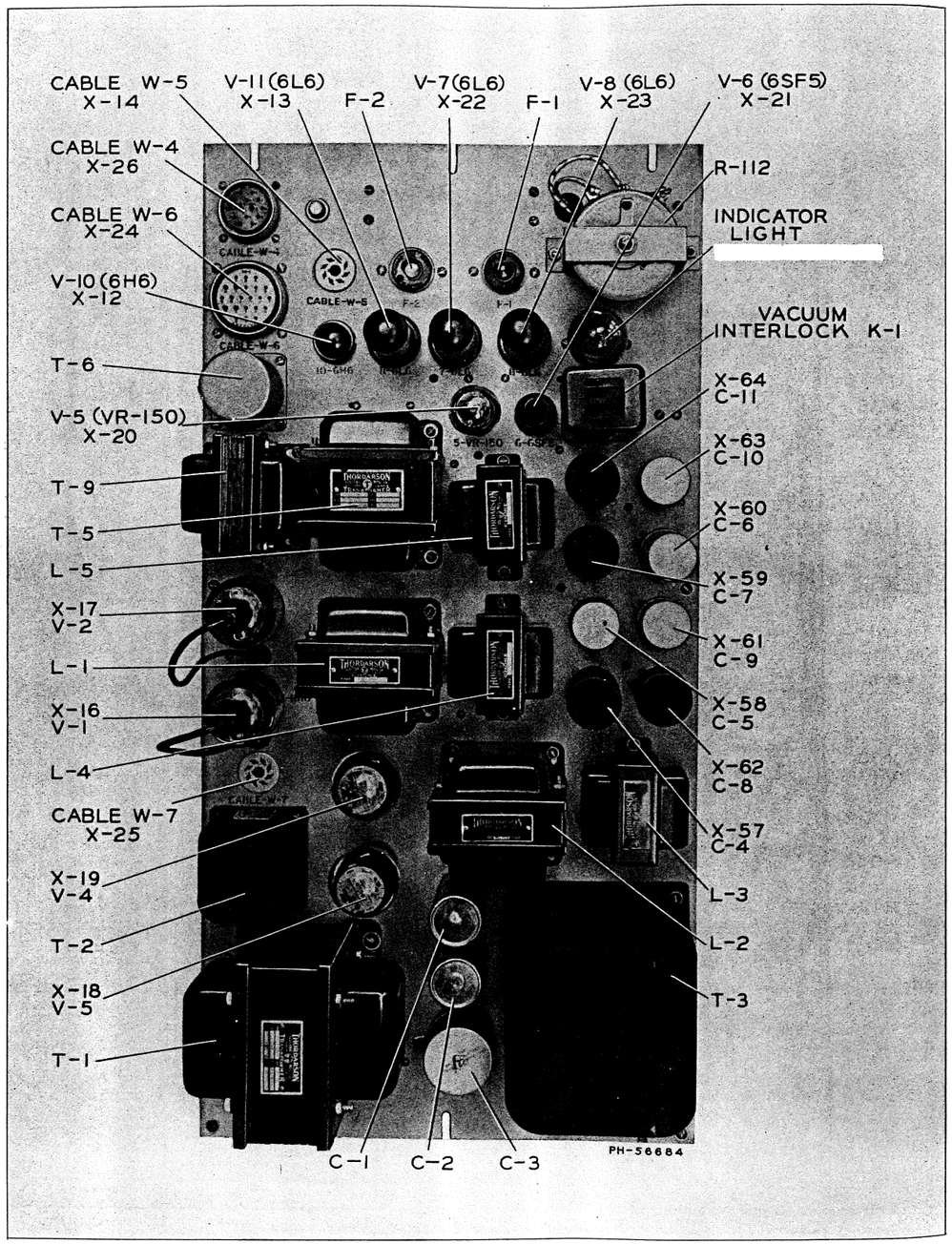


Figure 57—Bottom Chassis, Front View

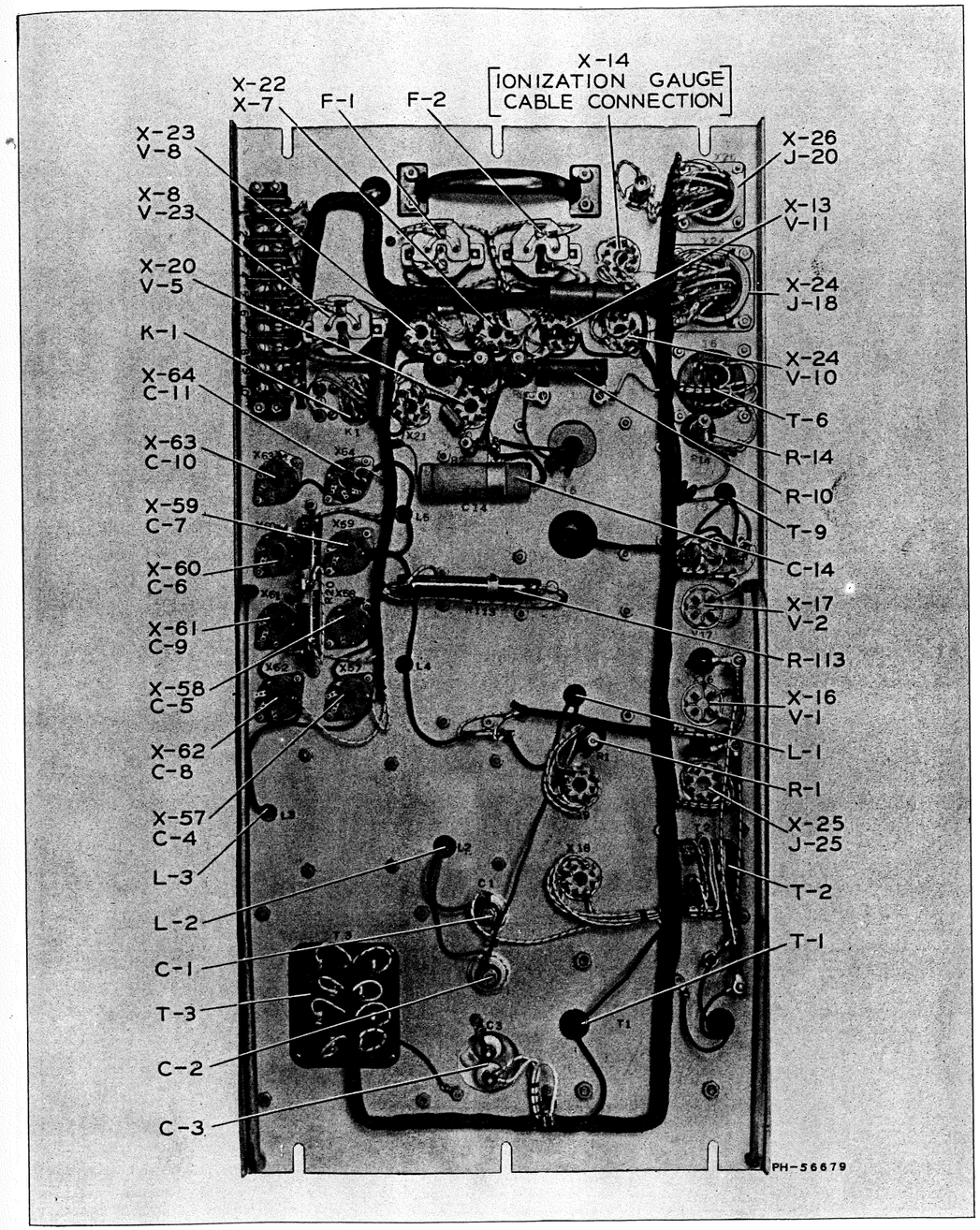


Figure 58—Bottom Chassis, Rear View

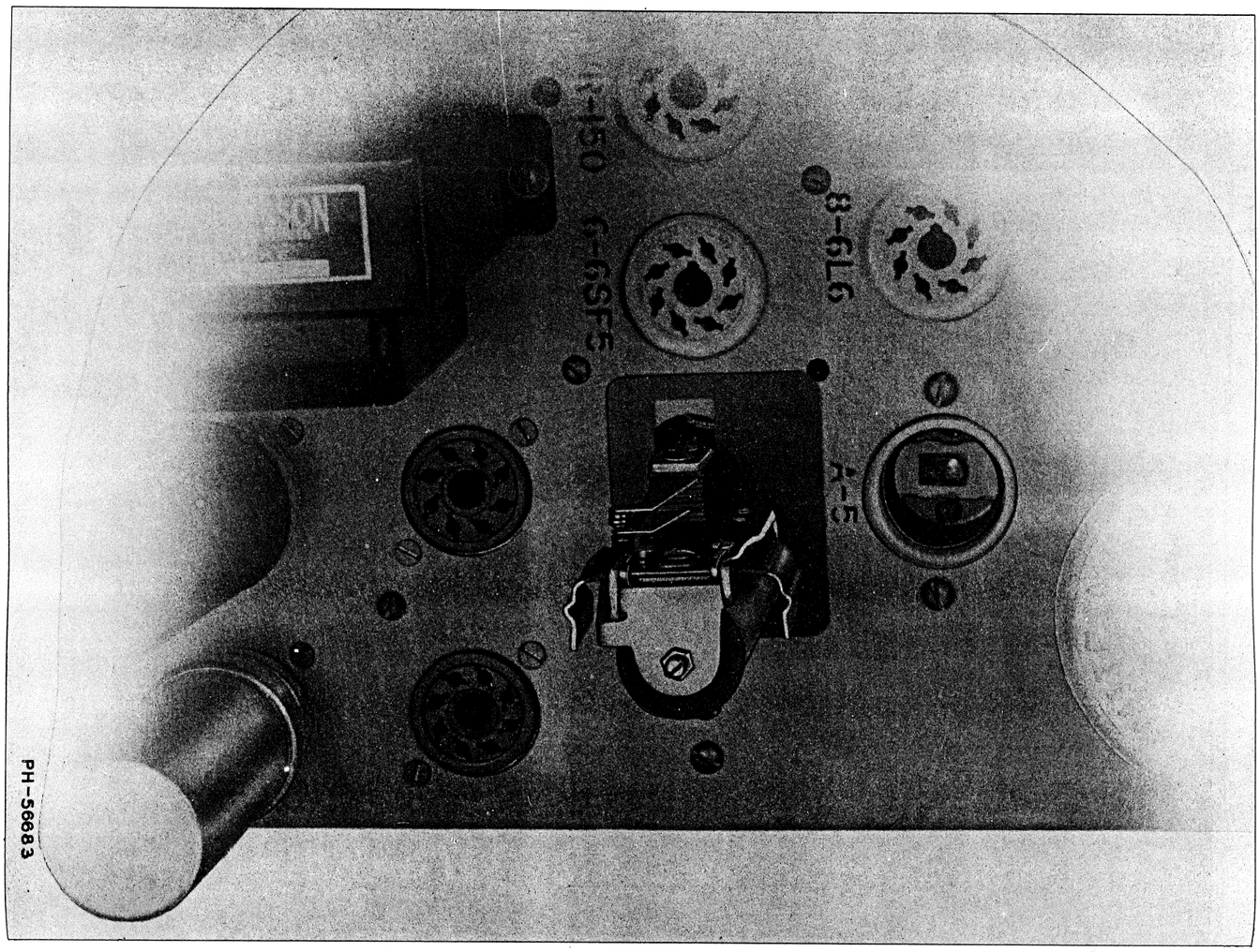


Figure 59—Vacuum-Interlock Relay, Close-up View

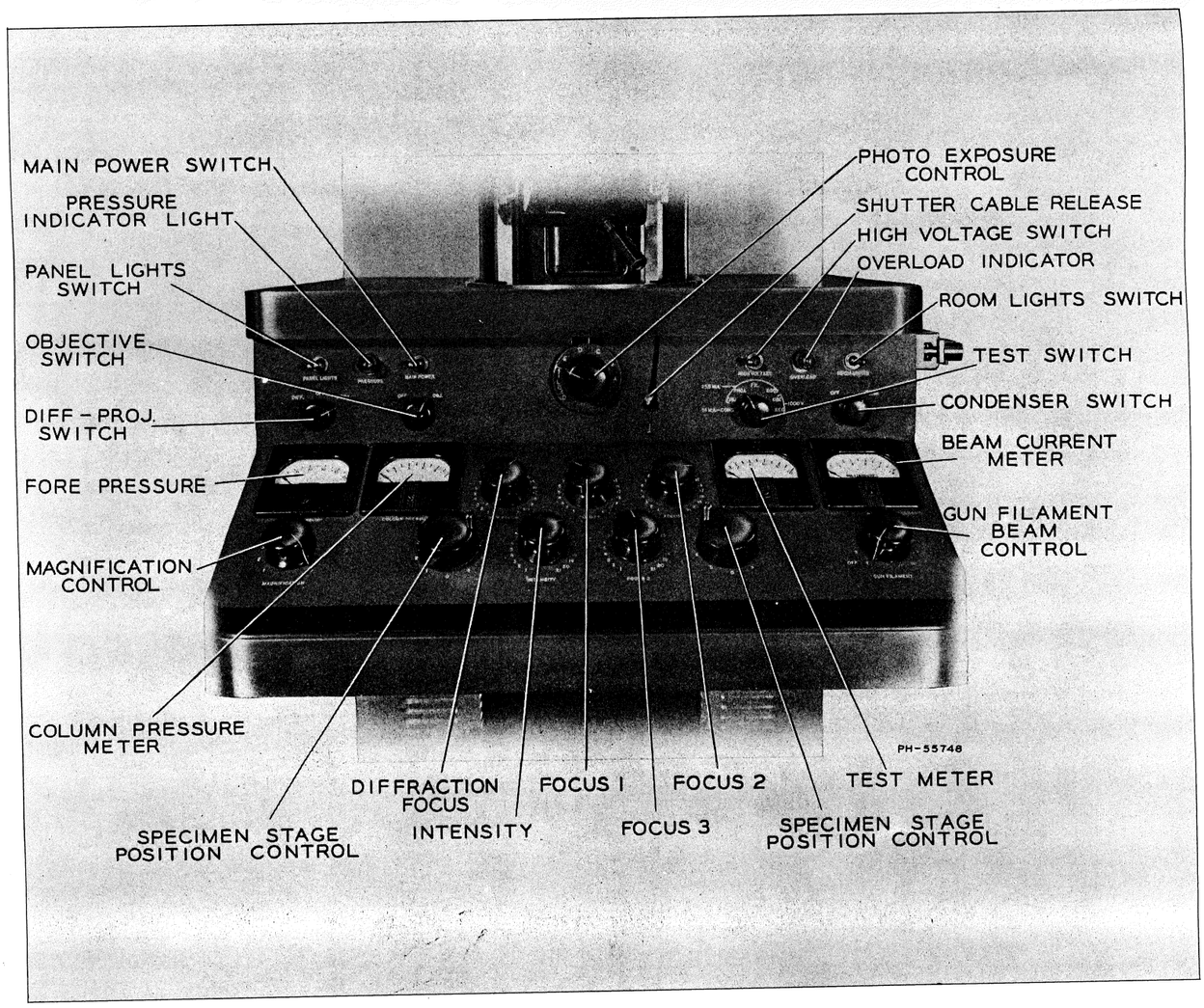


Figure 60—Control Panel, Front View

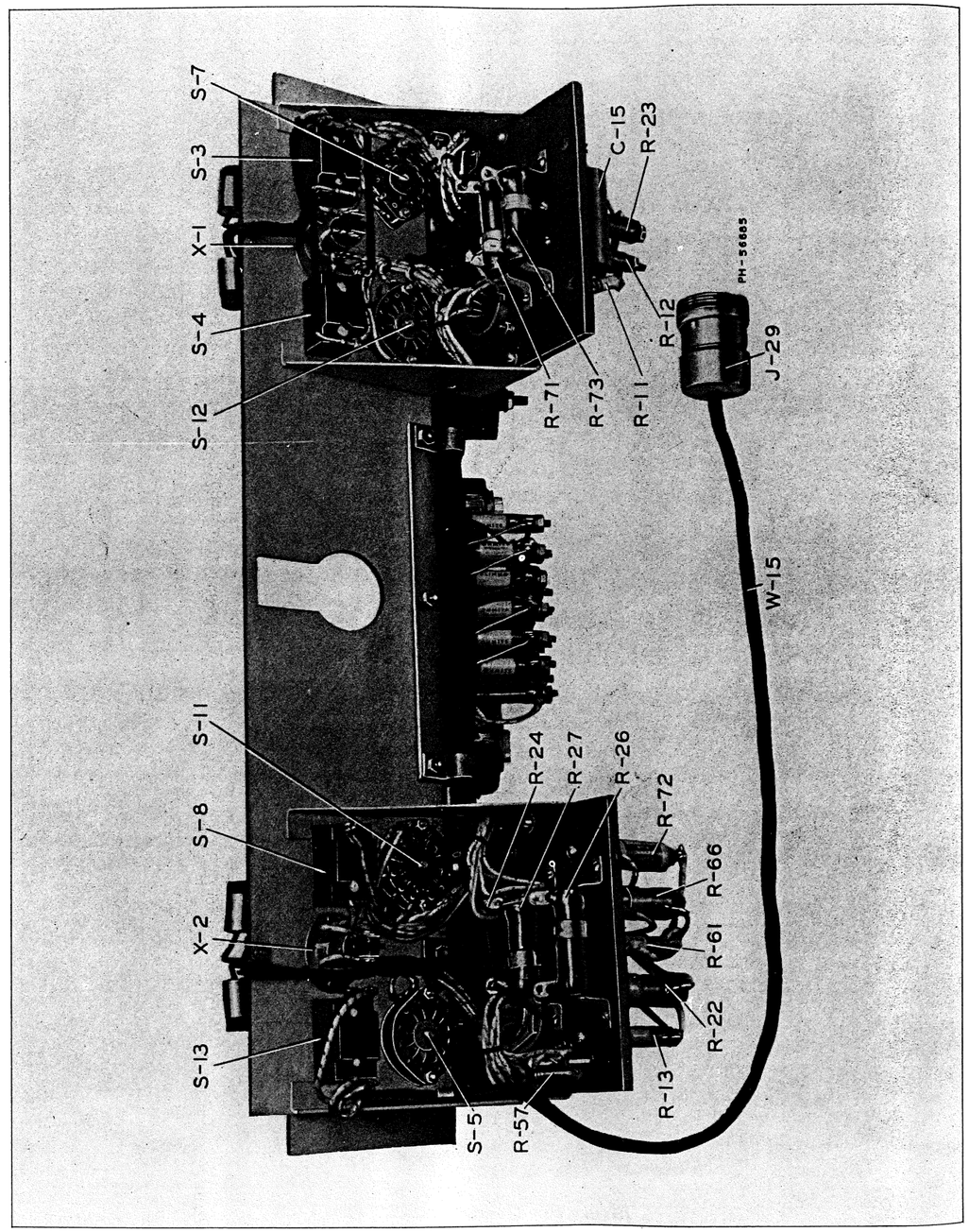


Figure 61—Control Panel, Rear View

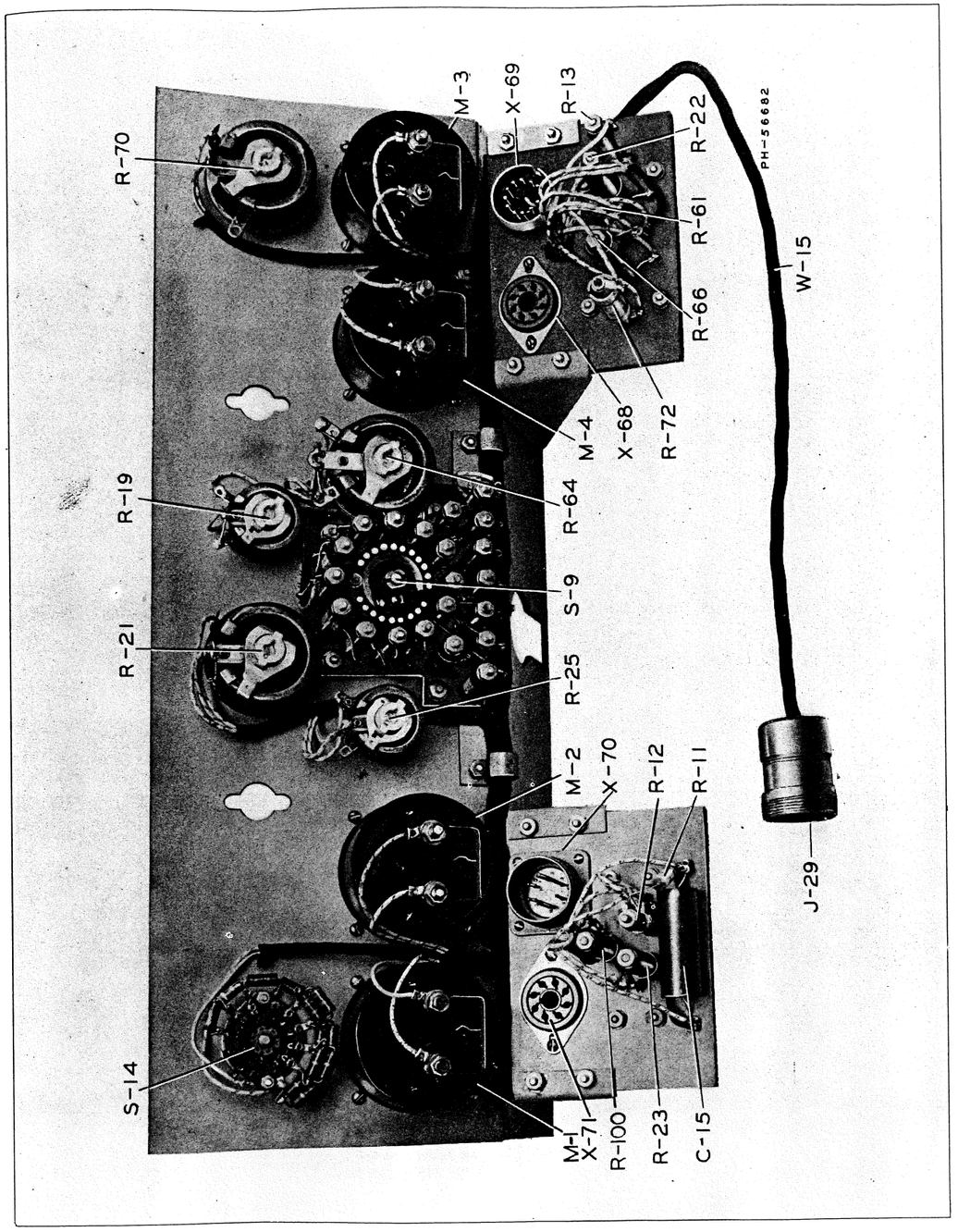


Figure 62—Control Panel, Bottom View

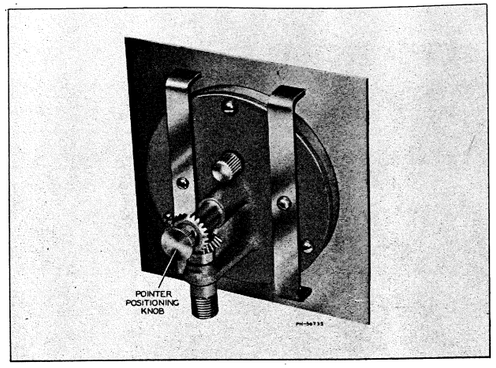


Figure 63—Valve Control Dial, Rear View

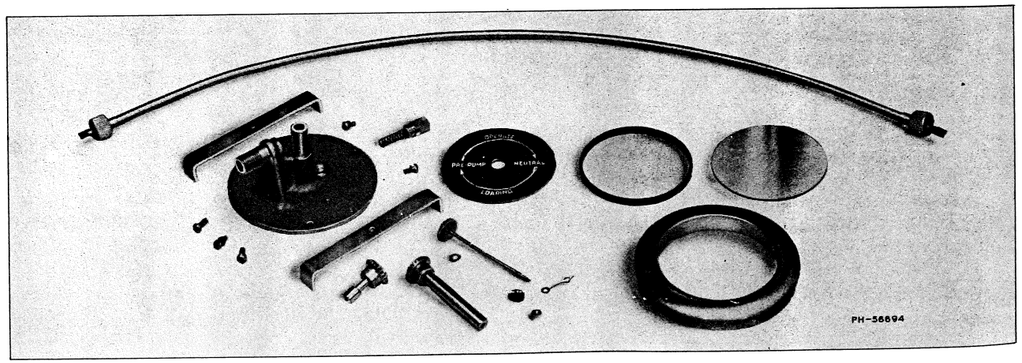


Figure 64—Valve Dial Parts

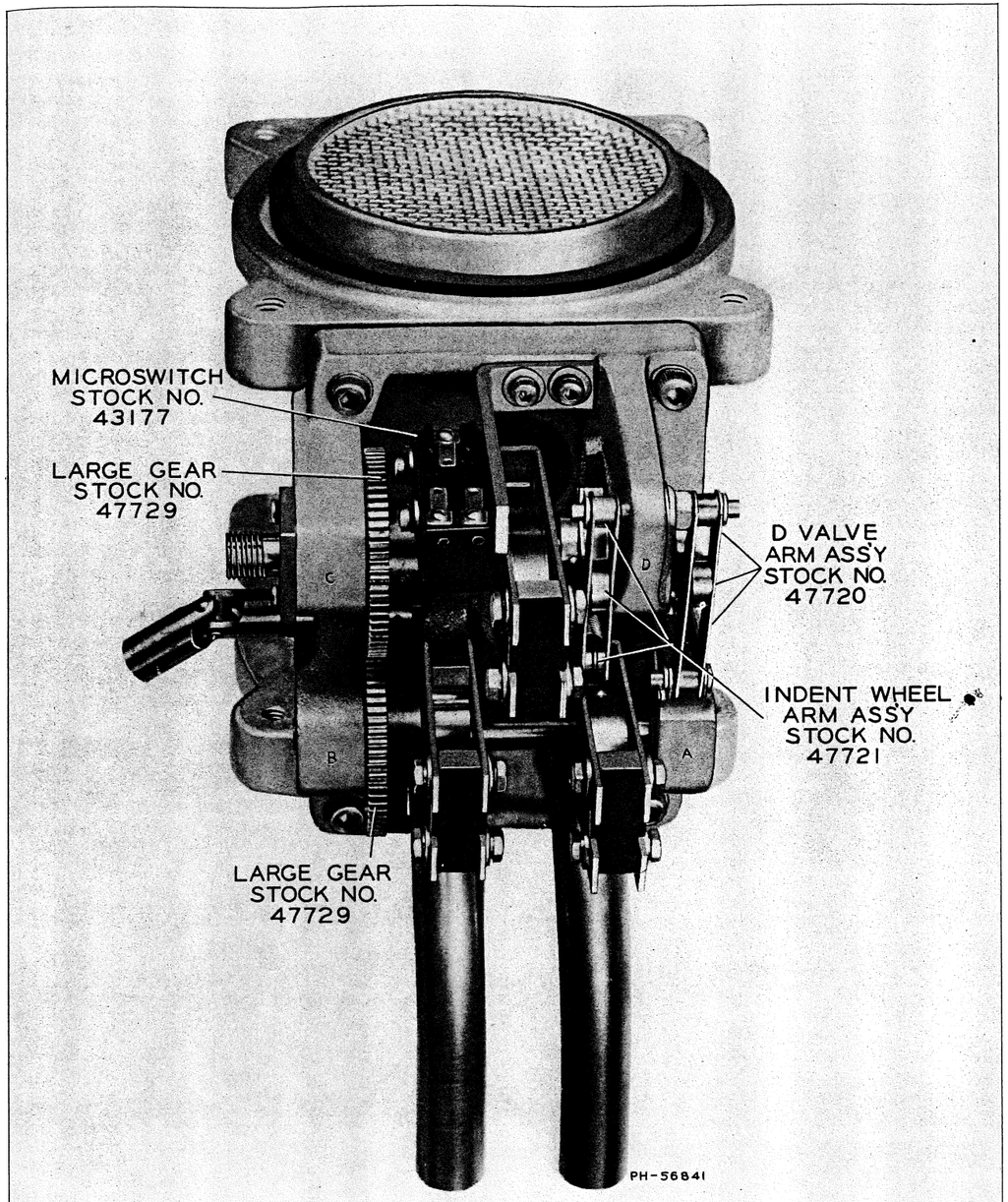


Figure 65—Valve Block

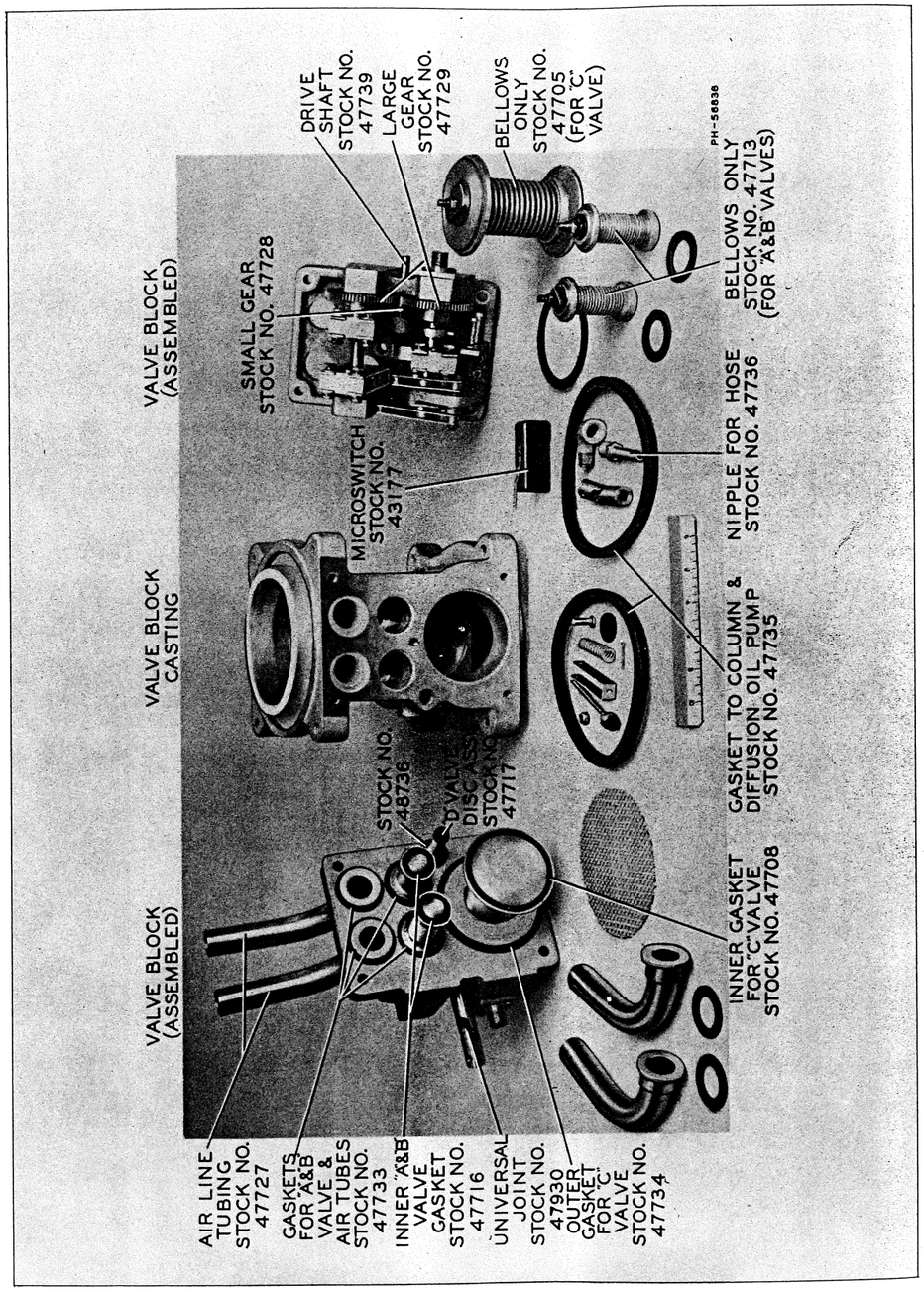


Figure 66—Valve Block Parts

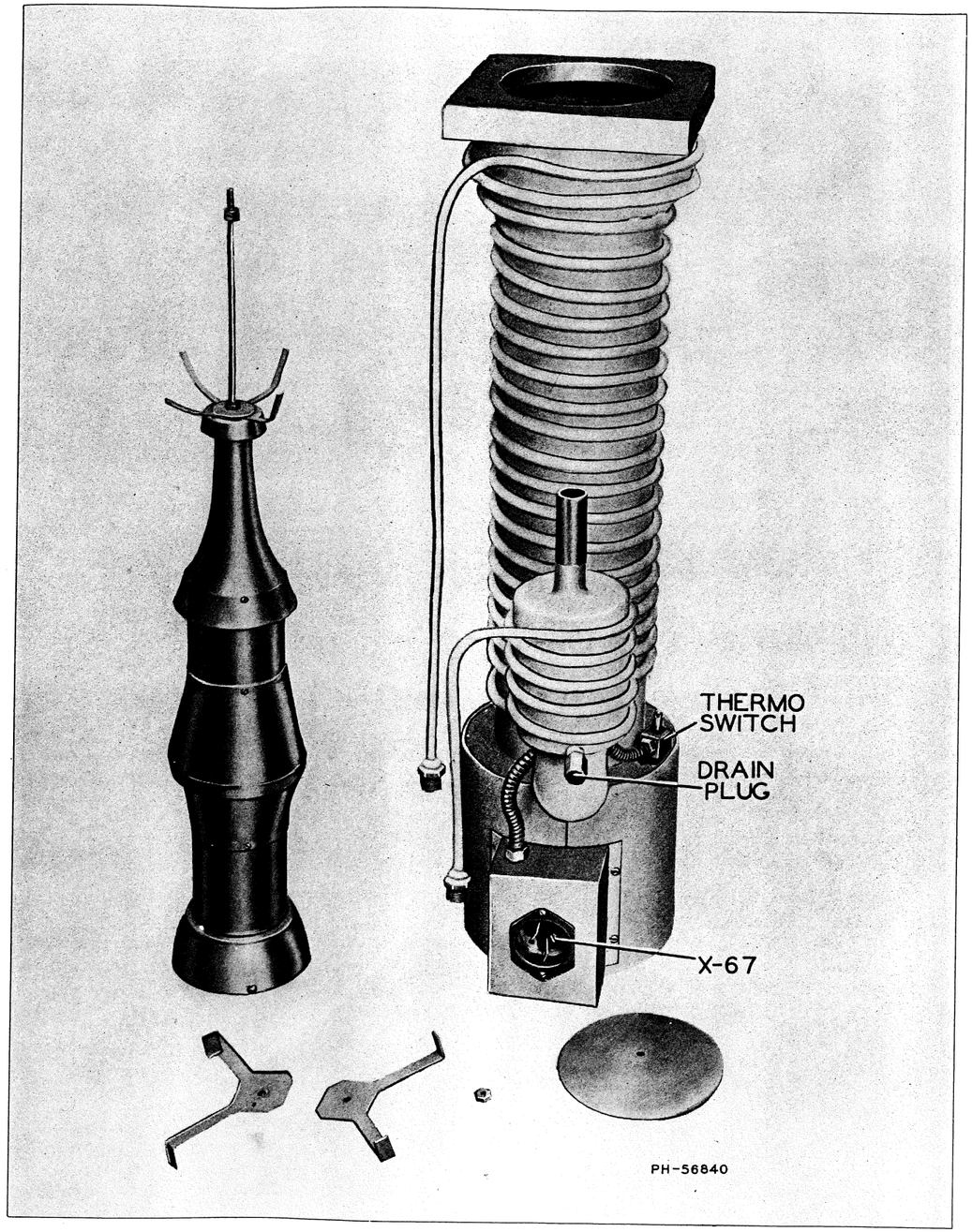


Figure 67—Diffusion Pump, Disassembled

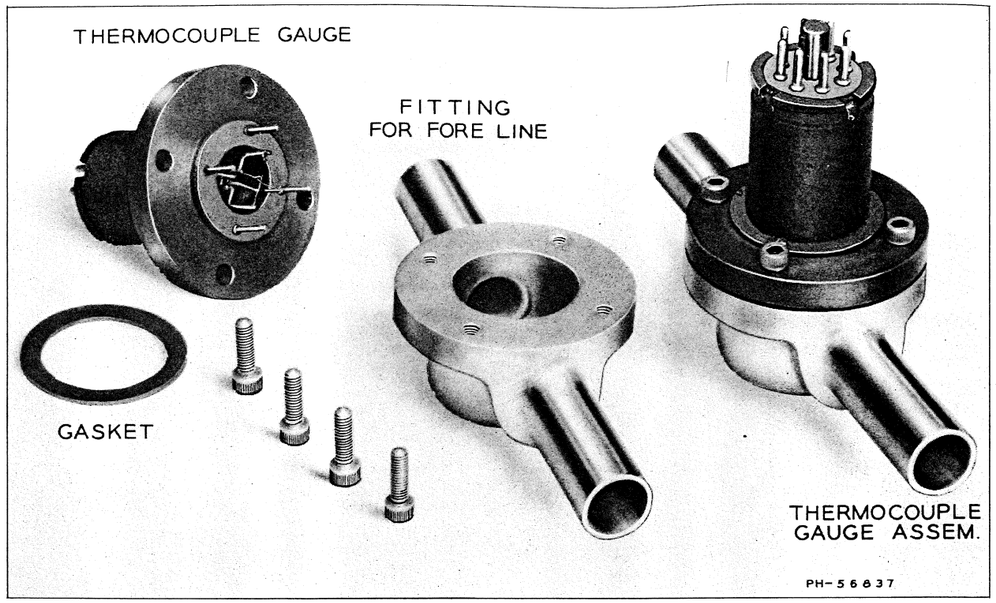


Figure 68A—Thermocouple Gauge, Electron Microscope, Types EMU-1 and EMU-2

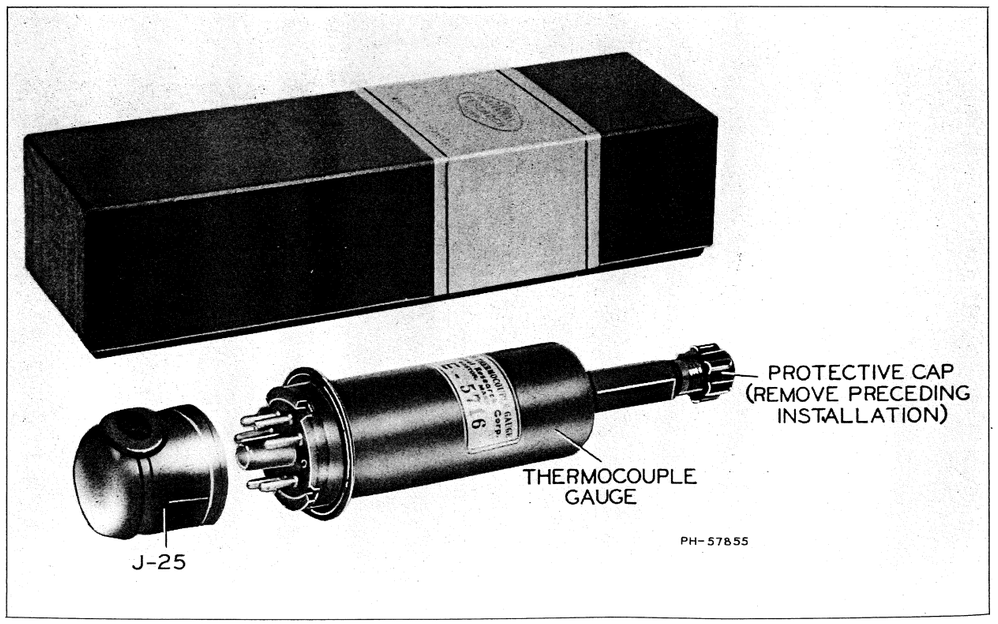


Figure 68B—Thermocouple Gauge, Electron Microscope, Type EMU-2A

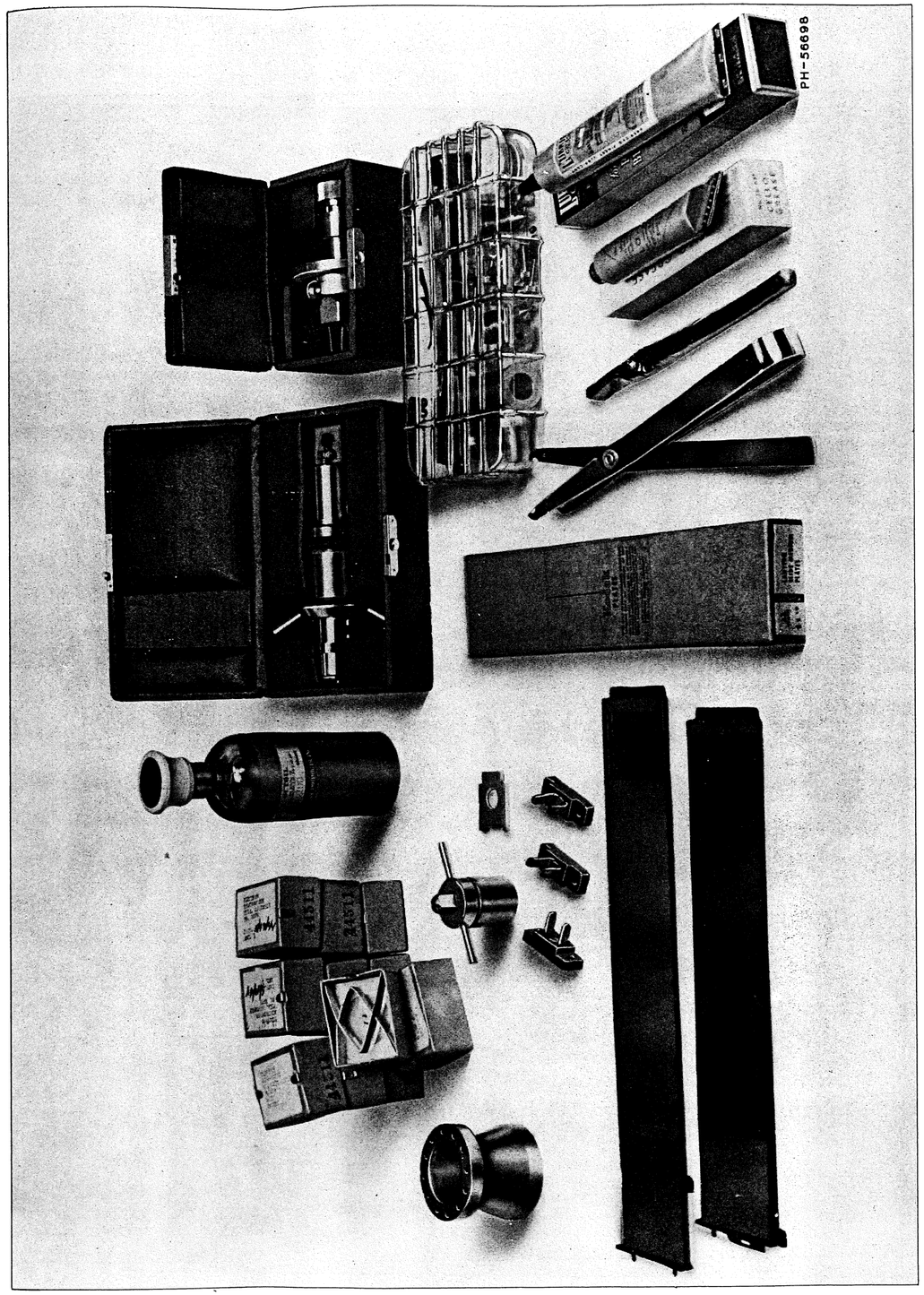


Figure 69—Accessory Kit

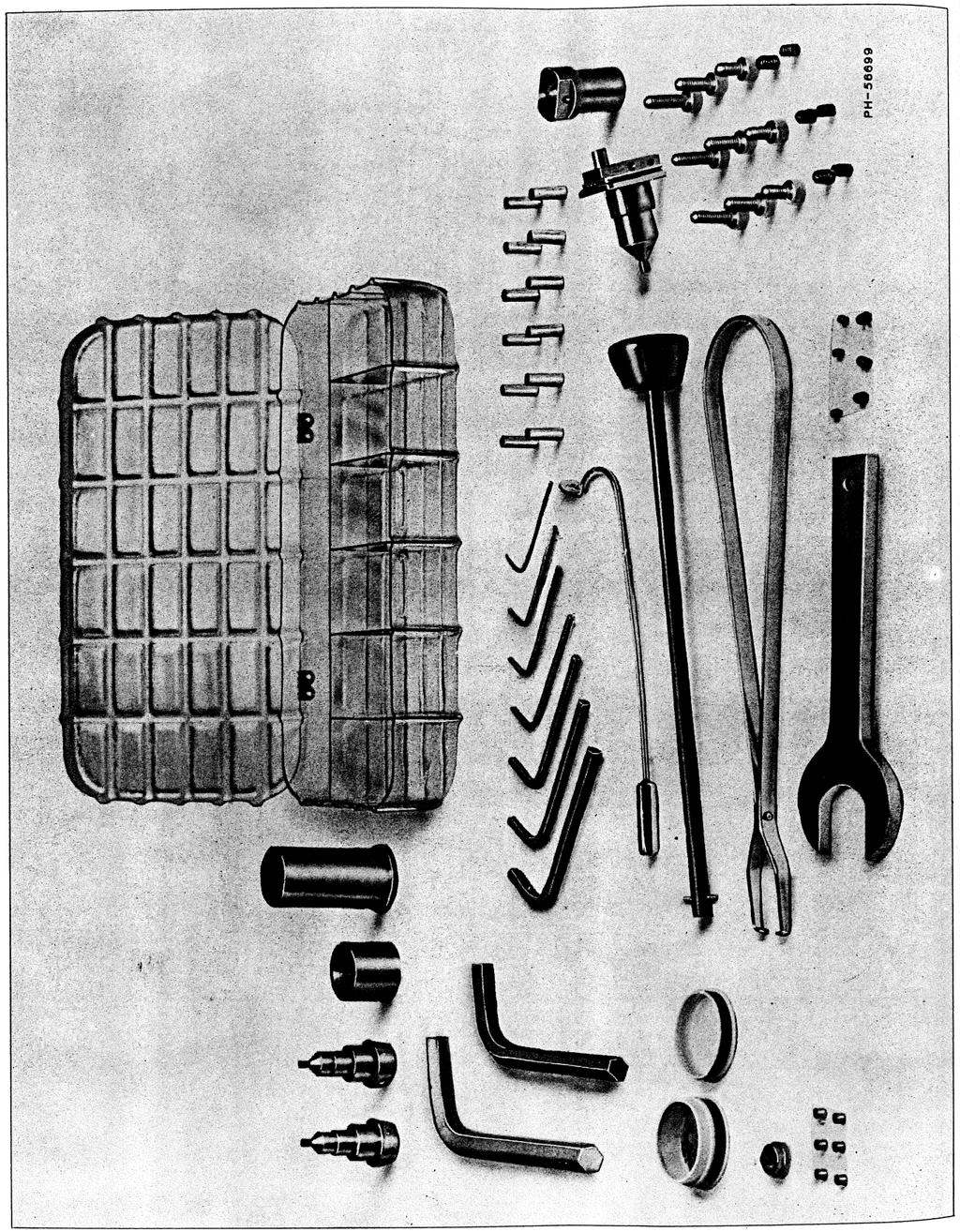


Figure 70—Accessory Kit, Contents of Plastic Box

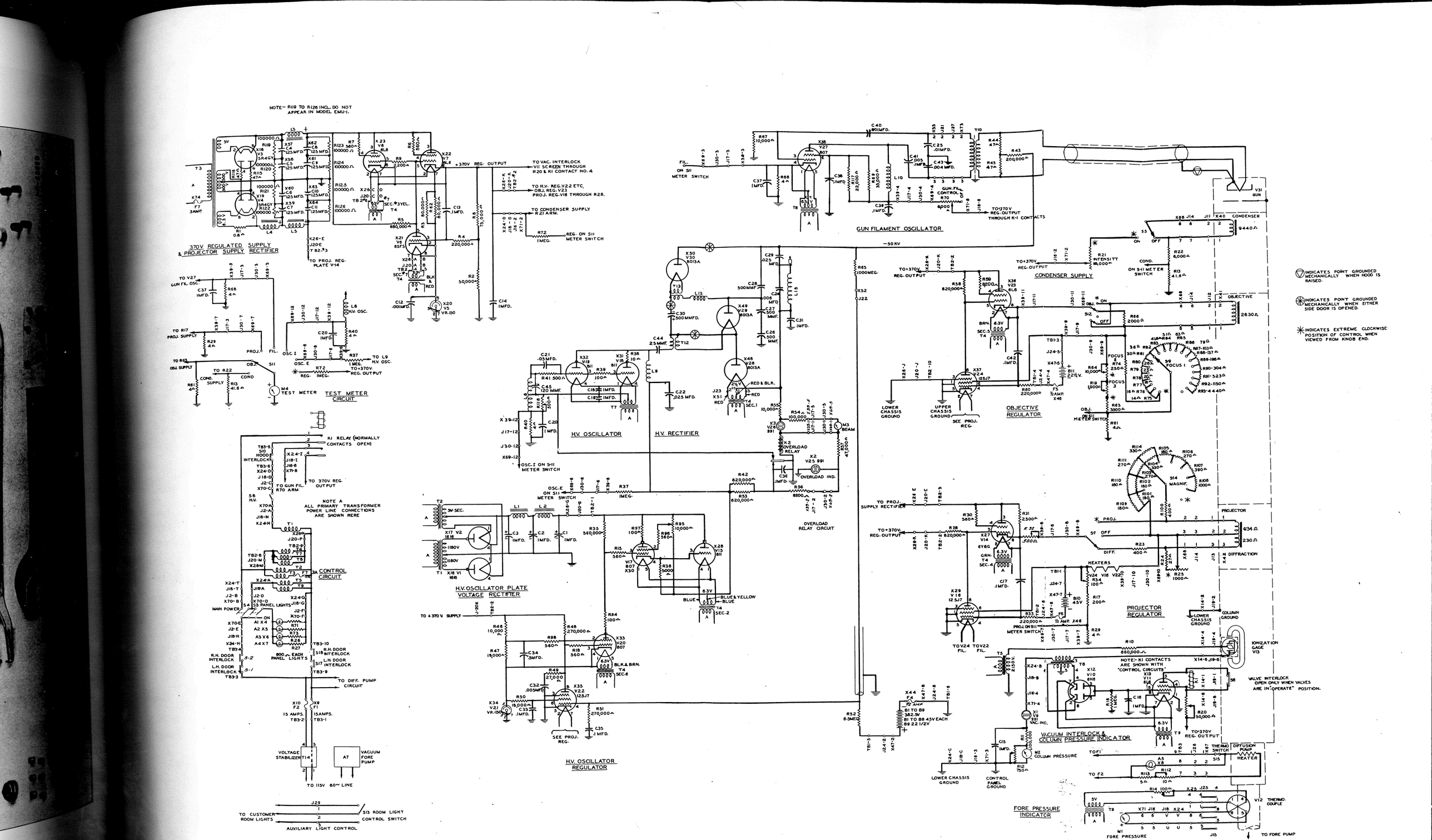


Figure 71A—Schematic Diagram, Electron Microscope, Types EMU-1 and EMU-2 (W-302952—Sub. 13)

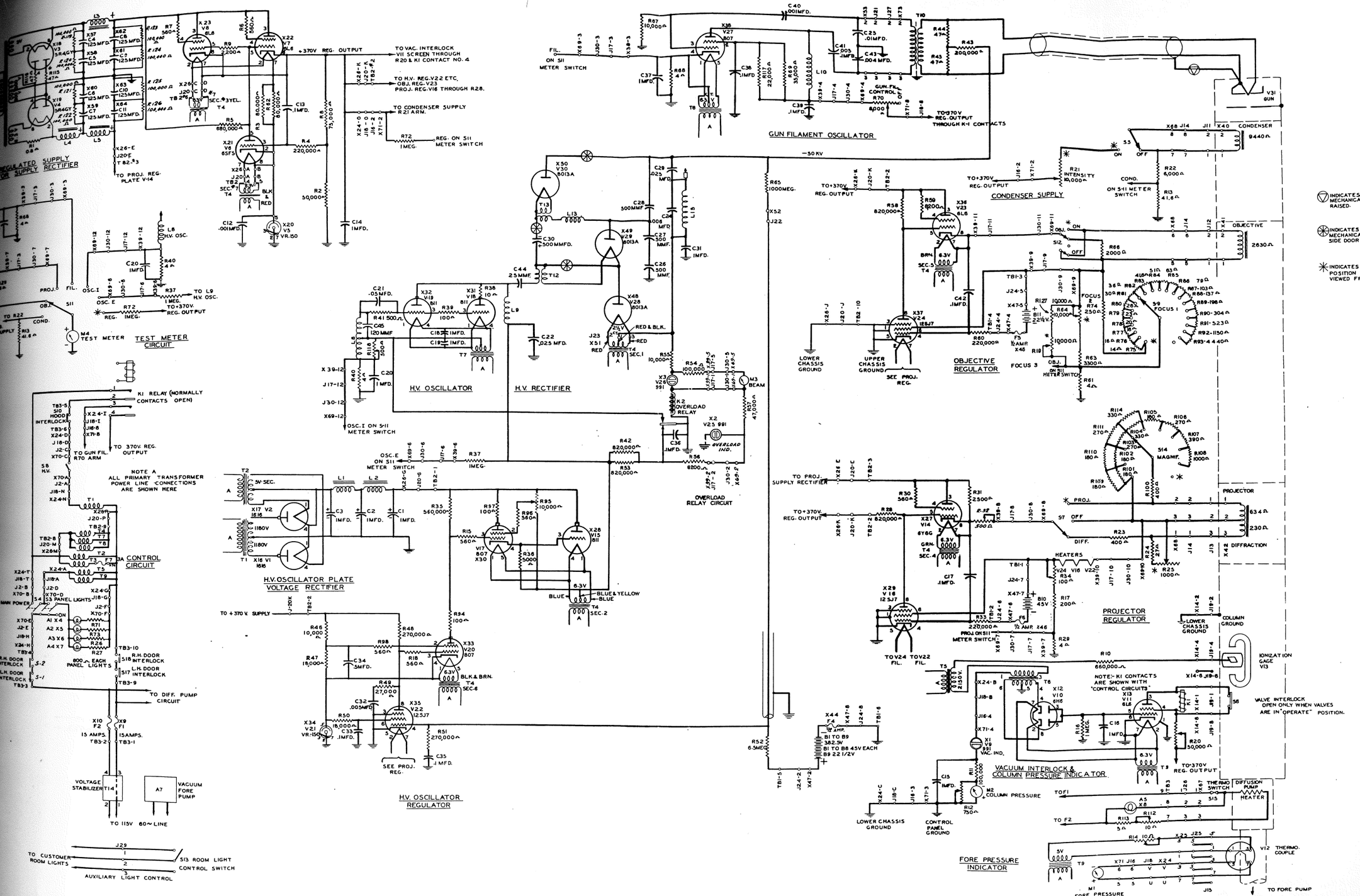


Figure 71B—Schematic Diagram, Electron Microscope, Type EMU-2A (W-302979—Sub. 1)

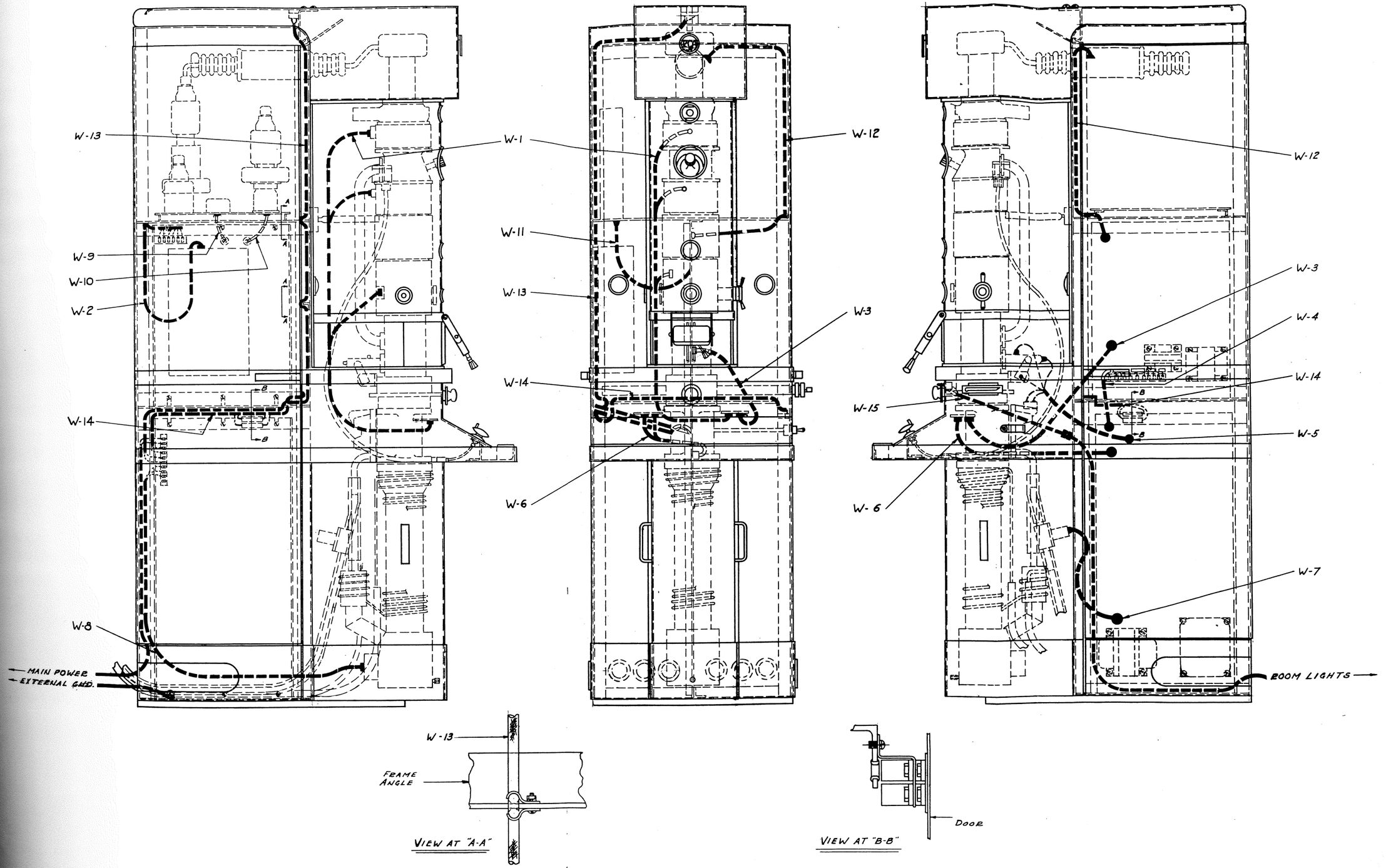


Figure 72—Cabinet Wiring Diagram
(W-302972—Sub. 0)

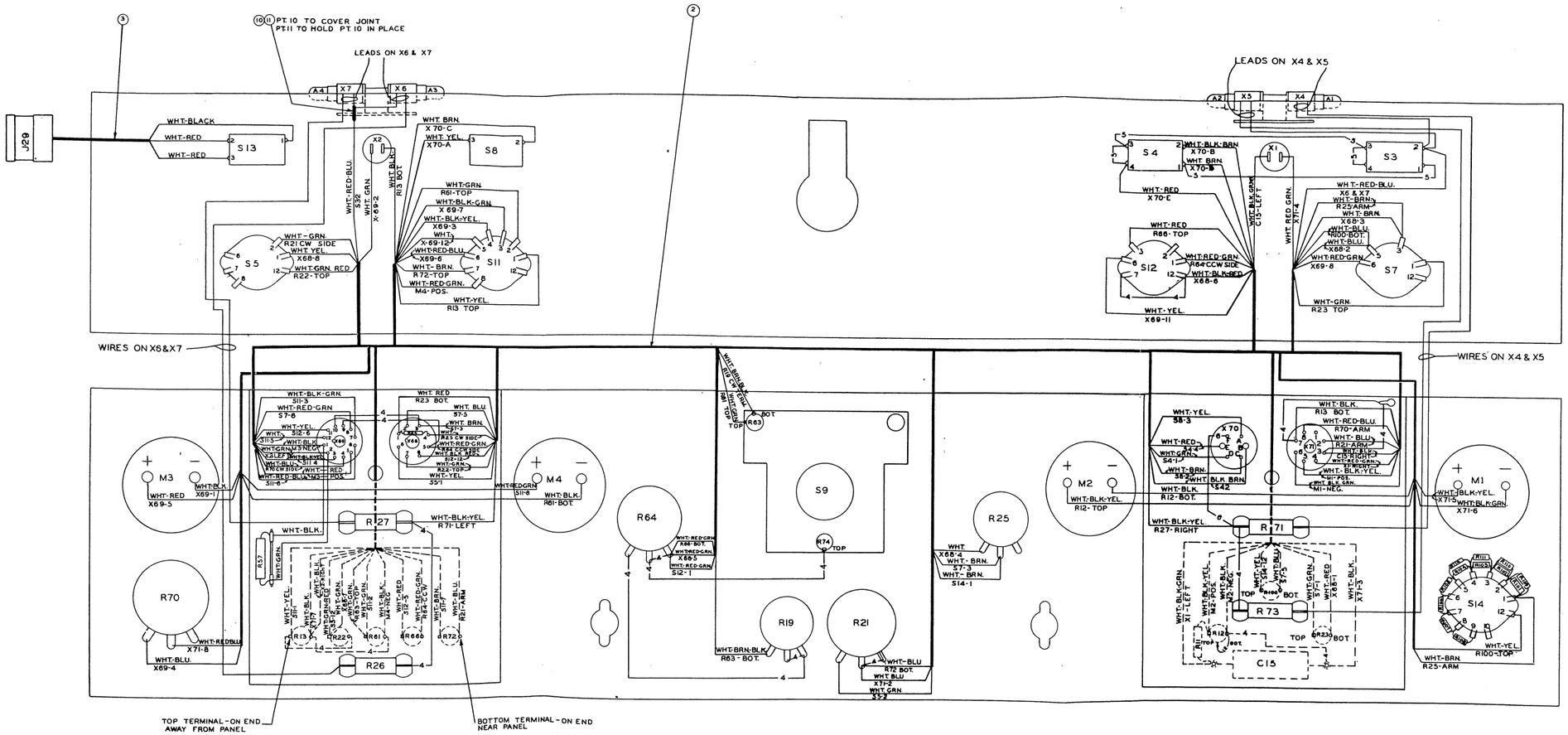


Figure 73A—Connection Diagram, Control Panel, Electron Microscope, Types EMU-1 and EMU-2 (W-302959—Sub. 1)

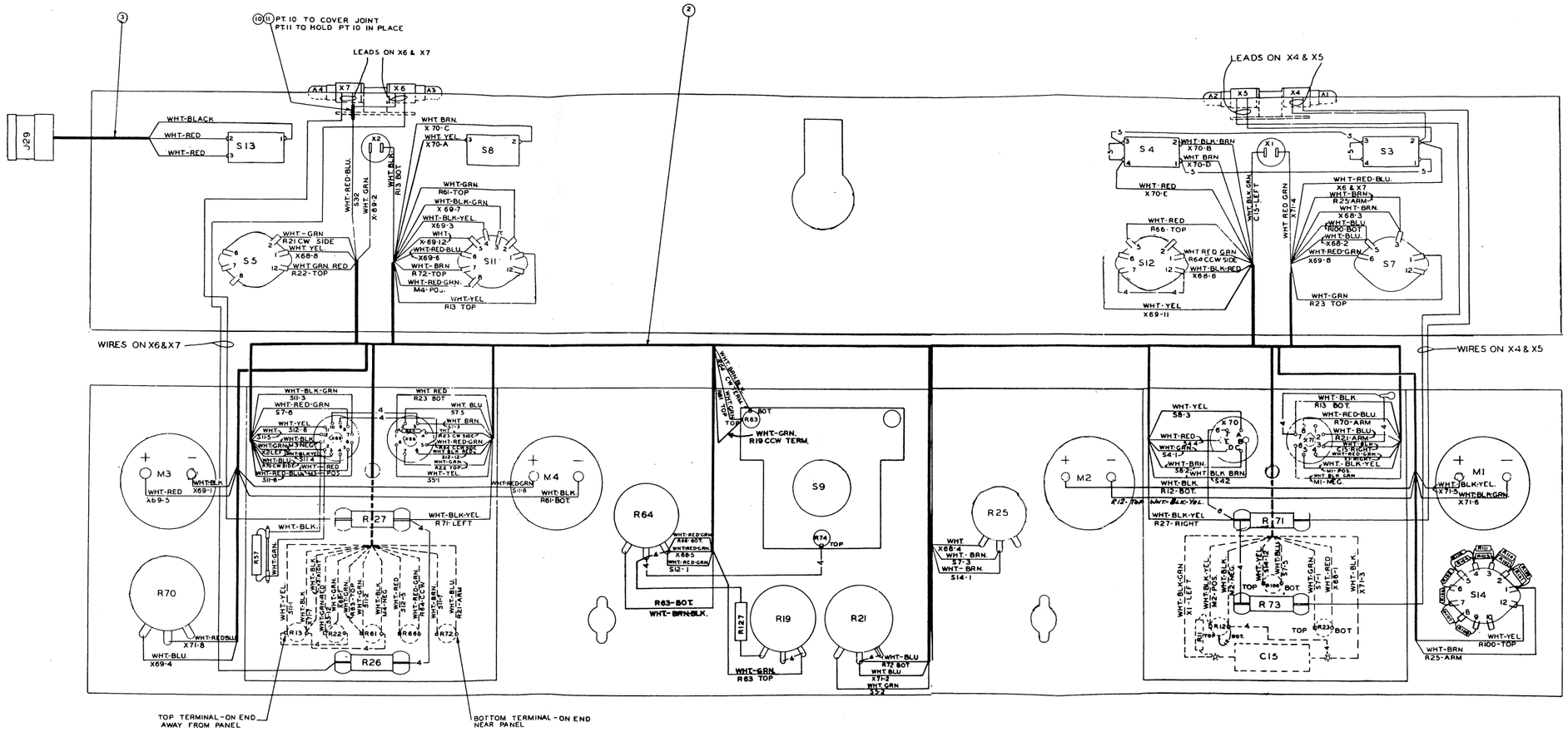
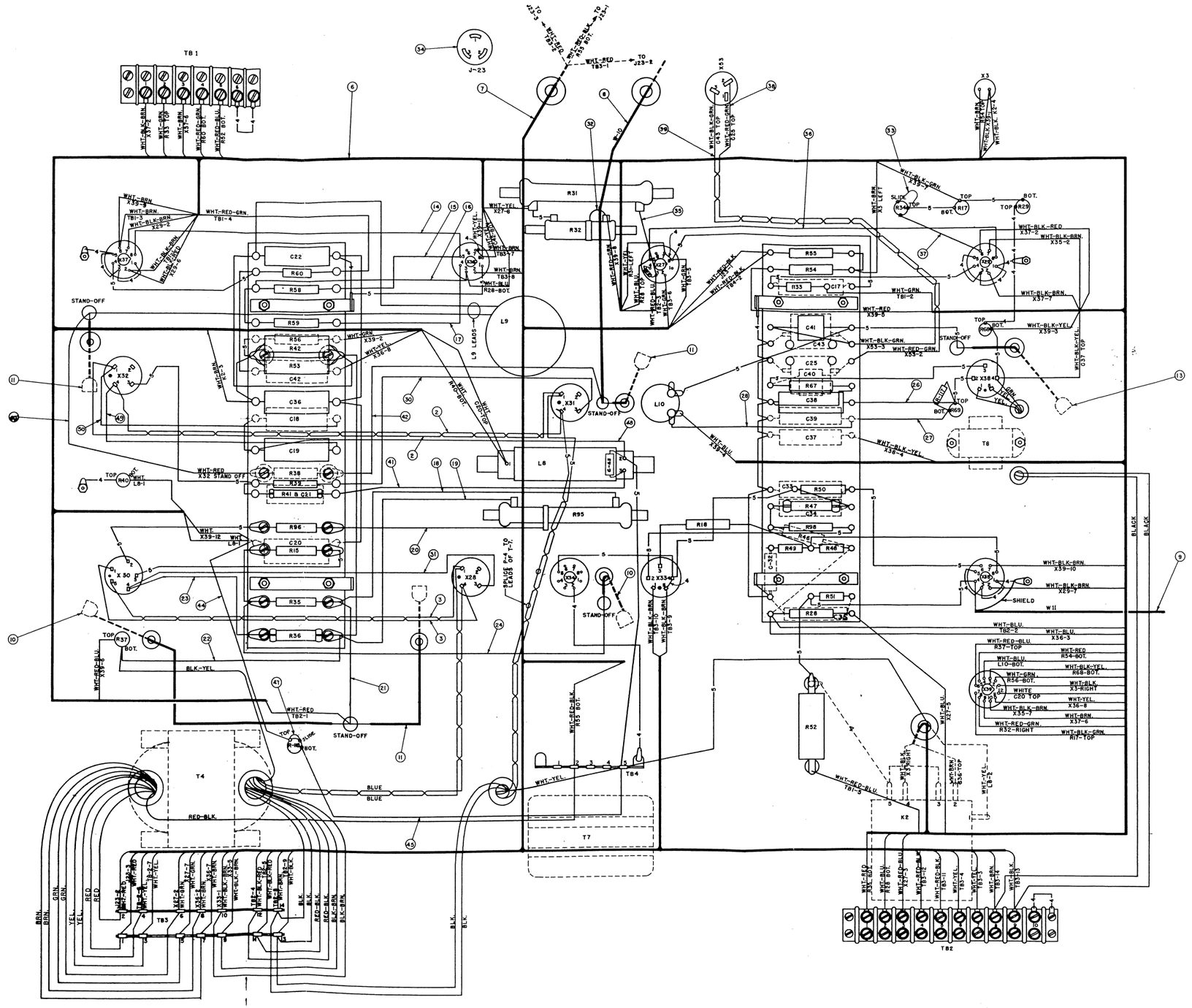


Figure 73B—Connection Diagram, Control Panel, Electron Microscope, Type EMU-2A (WW-302930—Sub. 1)

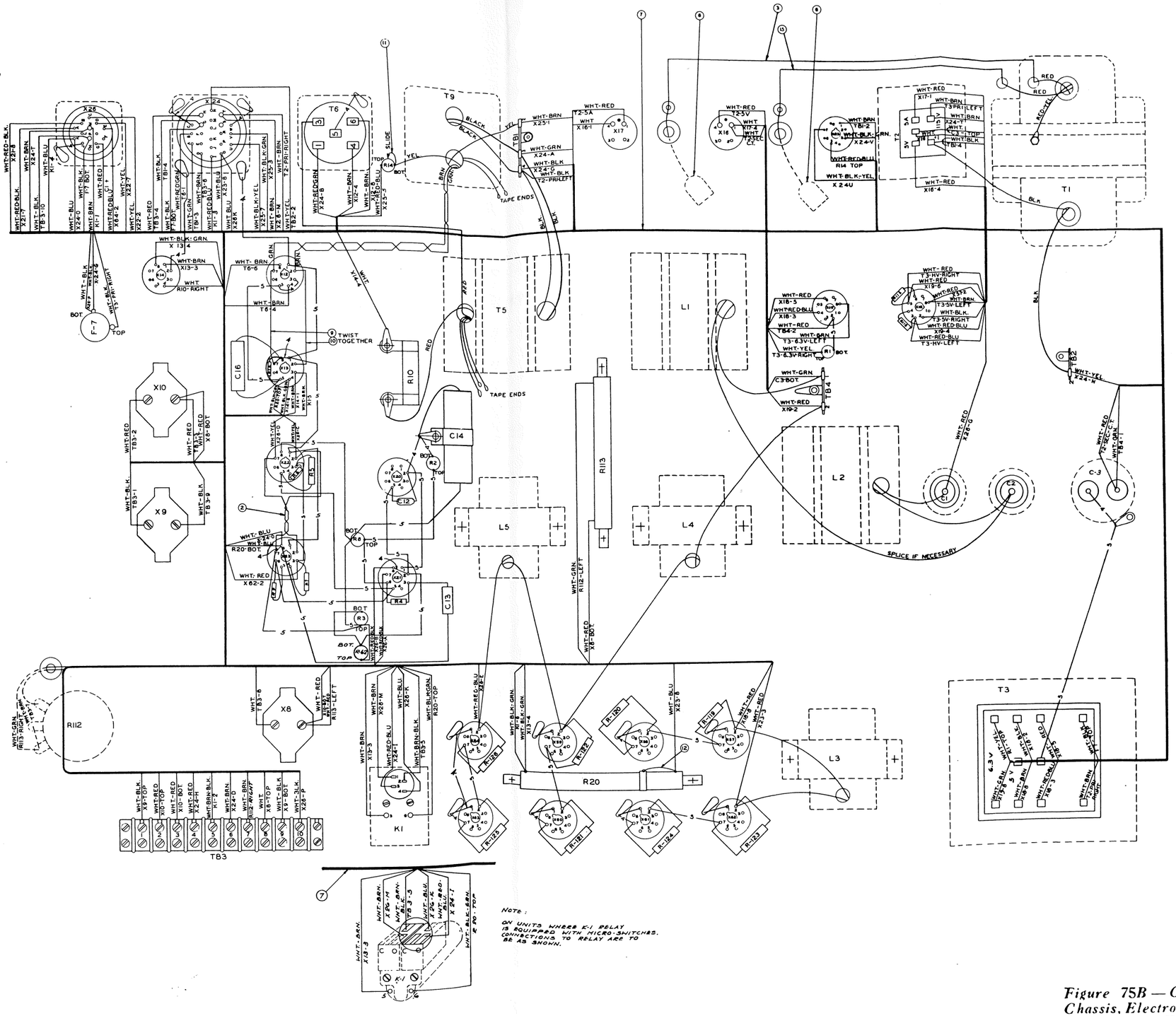

TB 1
J-23
TO J23-3
TO J23-1
TO J23-2
WHT-RED TB3-2
WHT-RED-BLK X35 BOT.
WHT-RED TB3-1
WHT-BLK-BRN. X39-4
WHT-BRN. TB1-3
WHT-BLK-BRN. X29-2
WHT-RED-GRN. TB1-4
WHT-BLK-GRN. X39-1
WHT-BLK-GRN. X39-5
WHT-YEL. X27-6
WHT-BRN. TB3-8
WHT-BLU. R28-BOT.
WHT-BRN. TB3-7
WHT-BLU. X35-LEFT
WHT-RED-BLU. X35-RIGHT
WHT-BLK. X35-6
WHT-RED-BLK. TB4-2
WHT-BRN. TB3-9
WHT-BRN. X3 LEFT
WHT-BLK-GRN. X39-3
WHT-BLK-RED X37-2
WHT-BLK-BRN. X35-2
WHT-BLK-BRN. X37-7
WHT-GRN. TB1-2
WHT-RED X39-6
WHT-BLK-YEL. X39-3
WHT-BLK-YEL. C37 TOP
WHT-BLU. X39-4
WHT-BLK-YEL. X38-4
WHT-BLK-BRN. X39-10
WHT-BLK-BRN. X29-7
SHIELD
W11
WHT-BLU. TB2-2
WHT-BLU. X36-3
WHT-RED-BLU. R37-TOP
WHT-RED R54-BOT.
WHT-BLU. L10-BOT.
WHT-BLK-YEL. R68-BOT.
WHT-GRN. R56-BOT.
WHT-BLK X3-RIGHT
WHITE C20 TOP
WHT-YEL. X36-8
WHT-BLK-BRN. X35-7
WHT-BRN. X37-6
WHT-RED-GRN. R32-RIGHT
WHT-BLK-GRN. R11-TOP
WHT-BLU. X27-5
WHT-BLK. X3-RIGHT
WHT-BRN. X36-TOP
WHT-YEL. L8-2
WHT-RED-BLU. TB1-5
WHT-RED X39-8
WHT-BLU. X28 BOT.
WHT-RED-BLU. X27-3
WHT-RED-BLK. TB3-12
WHT-YEL. TB3-11
WHT-BRN. TB3-14
WHT-BLK. TB3-13
WHT-RED-BLK. X35 BOT.
WHT-BLK-BRN. TB3-9
WHT-BLU. TB2-1
WHT-RED-BLK. R55 BOT.
WHT-YEL. TB4-1
WHT-RED-GRN. X39-2
WHT-YEL. X38-8
WHT-GRN. X39-2
WHT-RED-GRN. TB1-4
WHT-RED X32 STAND OFF
WHT. X39-12
WHT. L8-1
WHT-RED-BLU. X39-8
BLK-YEL.
WHT-RED TB2-1
WHT-YEL. TB4-1
WHT-RED-BLK. TB4-2
WHT-BLK-BRN. TB3-9
WHT-BLK-BRN. TB3-10
WHT-BLK-BRN. TB3-11
WHT-BLK-BRN. TB3-12
WHT-BLK-BRN. TB3-13
WHT-BLK-BRN. TB3-14
WHT-BLK-BRN. TB3-15
WHT-BLK-BRN. TB3-16
WHT-BLK-BRN. TB3-17
WHT-BLK-BRN. TB3-18
WHT-BLK-BRN. TB3-19
WHT-BLK-BRN. TB3-20
WHT-BLK-BRN. TB3-21
WHT-BLK-BRN. TB3-22
WHT-BLK-BRN. TB3-23
WHT-BLK-BRN. TB3-24
WHT-BLK-BRN. TB3-25
WHT-BLK-BRN. TB3-26
WHT-BLK-BRN. TB3-27
WHT-BLK-BRN. TB3-28
WHT-BLK-BRN.

NOTE :-

ON UNITS WHERE K-1 RELAY IS EQUIPPED WITH MICRO-SWITCHES CONNECTIONS TO RELAY ARE TO BE AS SHOWN.

NOTE - R-119 TO R-126 INCL. DO NOT APPEAR IN MODEL EMU-1.

Figure 75A—Connection Diagram, Bottom Chassis, Electron Microscope, Types EMU-1 and EMU-2 (W-302957—Sub. 4)



① FOR ELECTRICAL PARTS LIST SEE M878458
WIRES MARKED '4' ARE PT.4-CUT TO SUIT.
WIRES MARKED '5' ARE PT.4 COVERED WITH PT.5-CUT TO SUIT. NOTATIONS TB1, TB2, TB4 ARE FOR REFERENCE ON THIS DRAWING ONLY. THESE NOTATIONS DO NOT REFER TO ANY LIST.

Figure 75B — Connection Diagram, Bottom Chassis, Electron Microscope, Type EMU-2A (W-302982—Sub. 5)

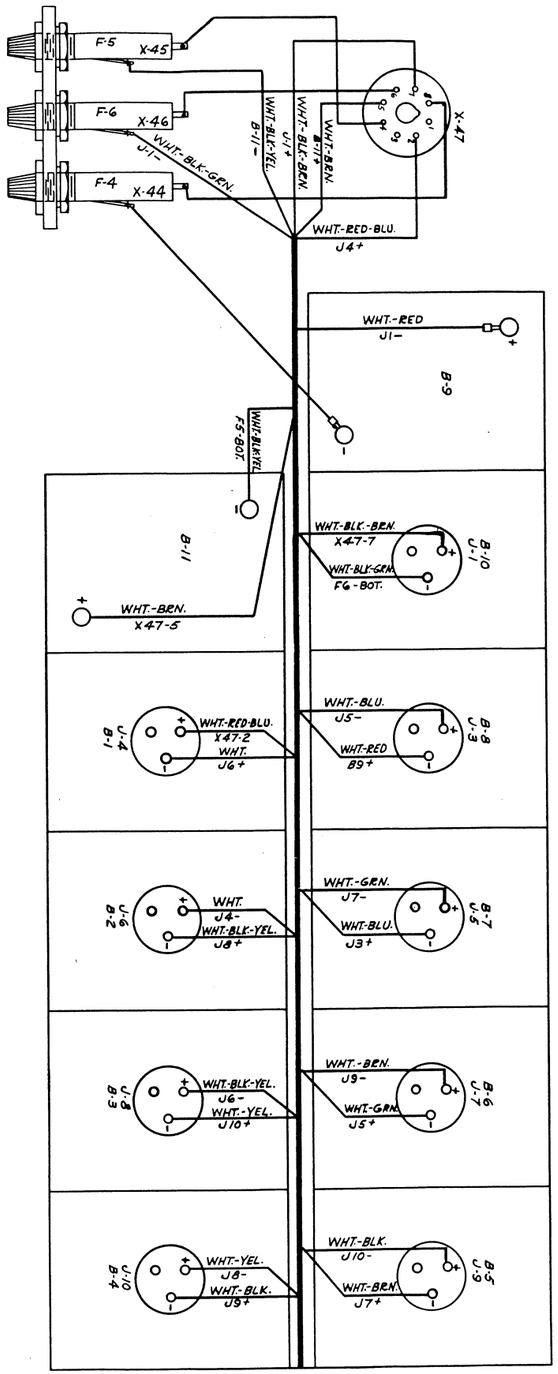


Figure 76—Connection Diagram, Battery Box (P-719138—Sub. 0)

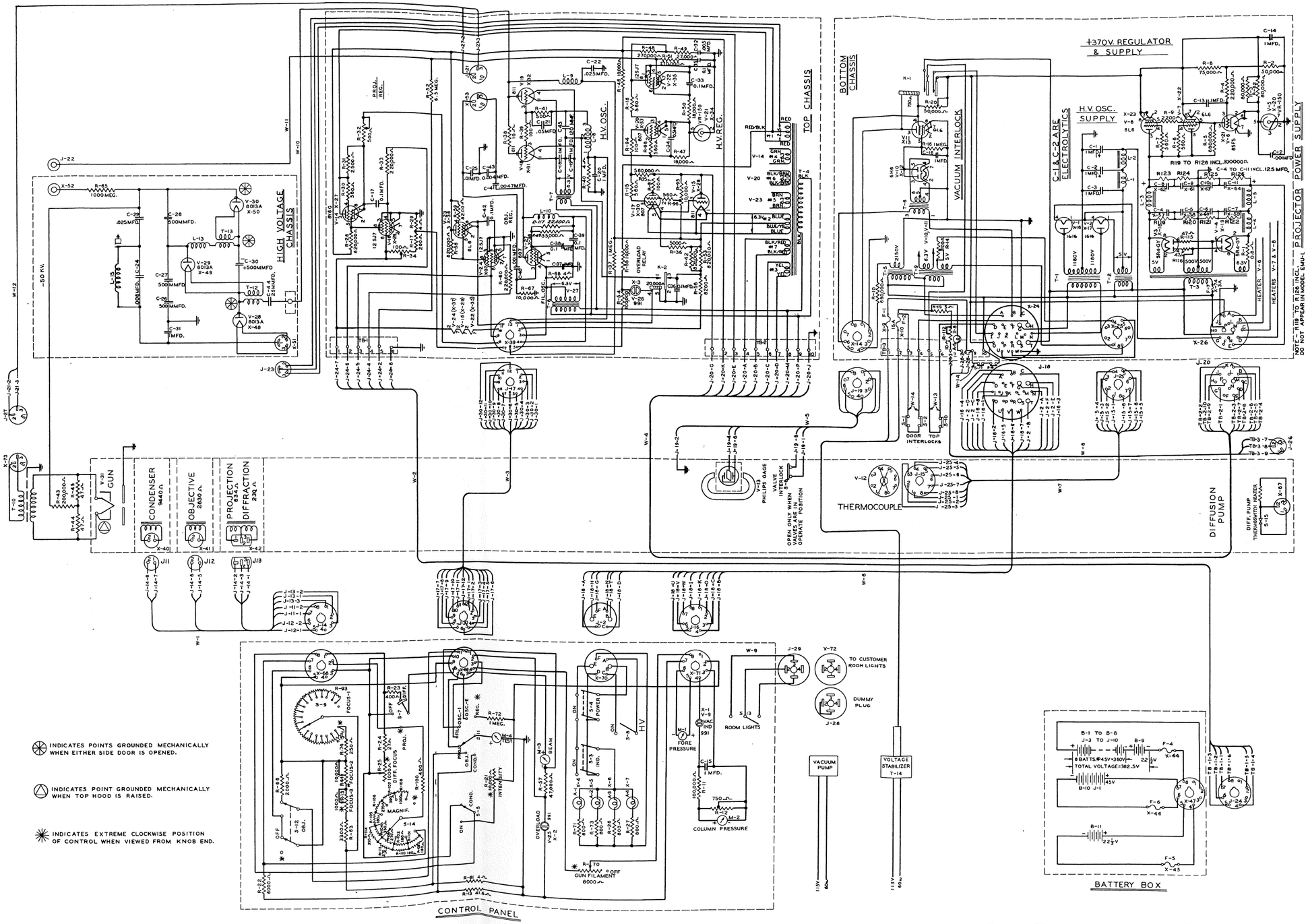


Figure 77A—Interconnection Diagram, Electron Microscope, Types EMU-1 and EMU-2 (W-302973—Sub. 1)

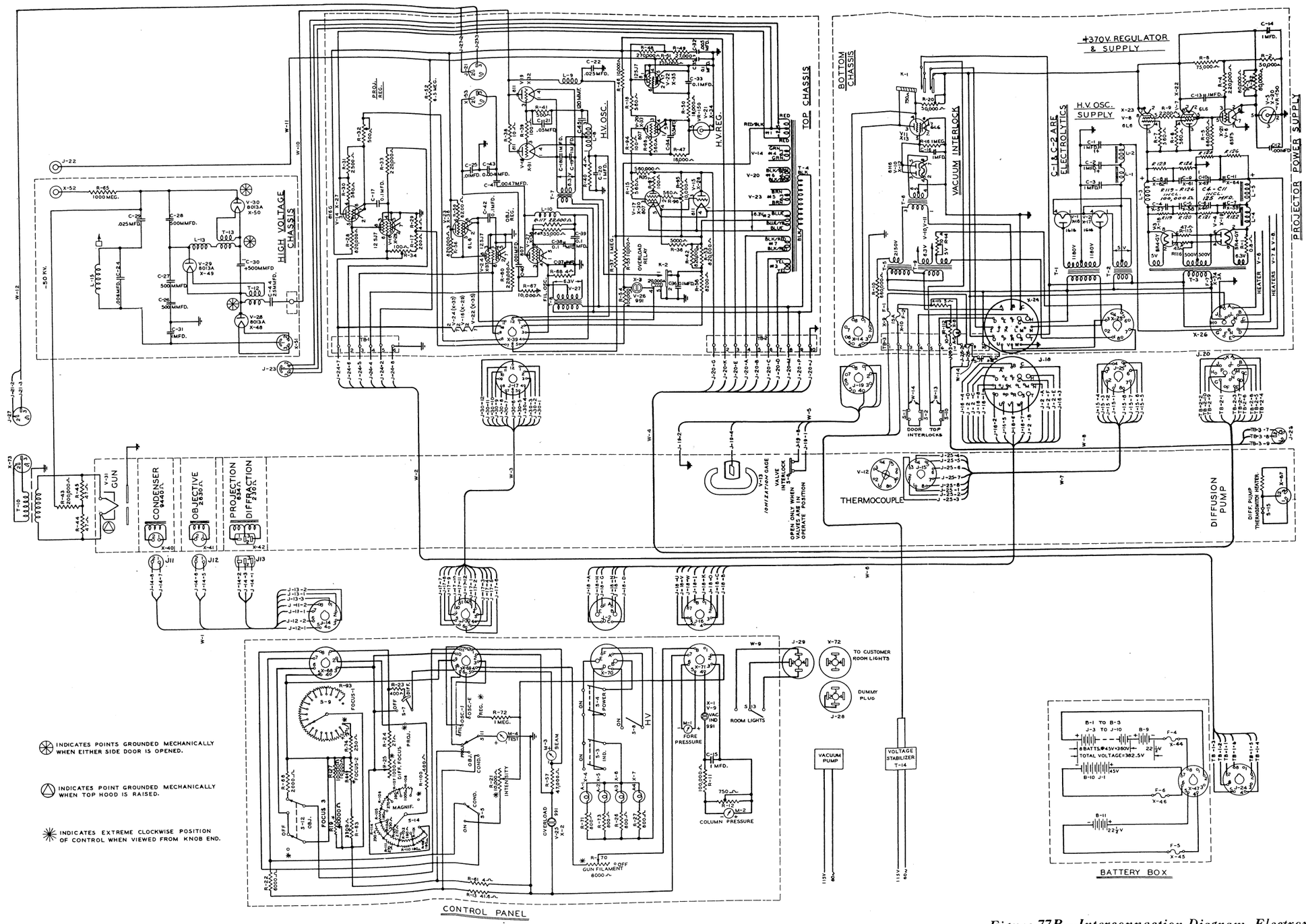


Figure 77B—Interconnection Diagram, Electron Microscope, Type EMU-2A (W-302981—Sub. 1)

TYPICAL MAGNIFICATION CHARACTERISTICS

TYPE EMU MICROSCOPE

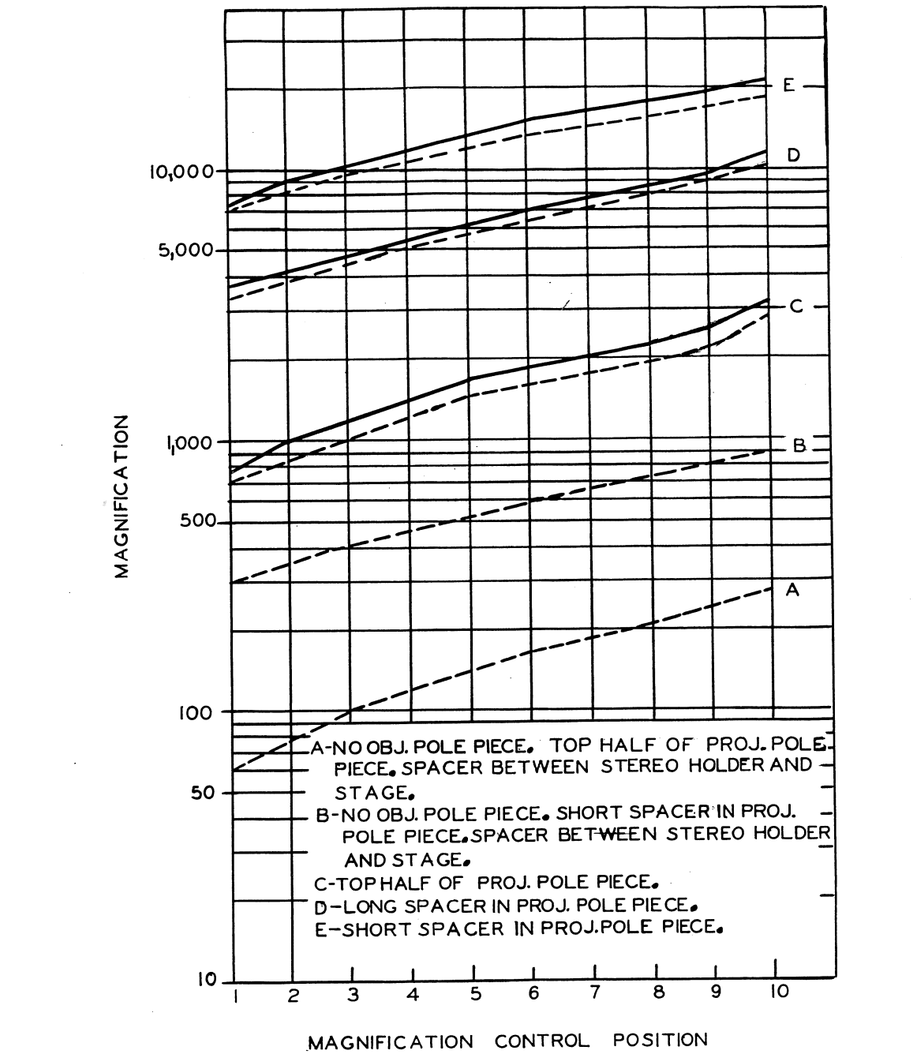
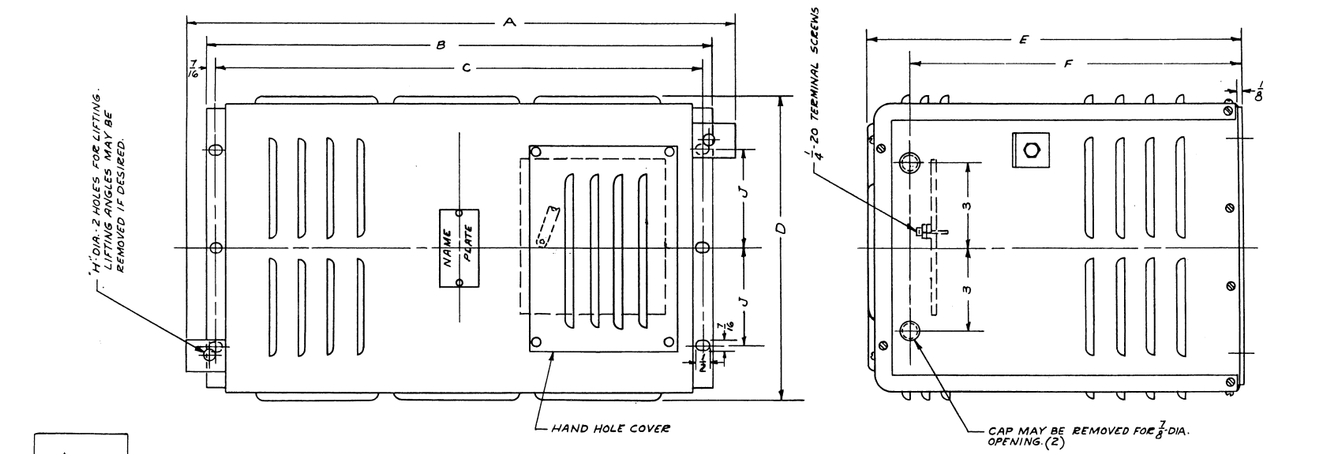
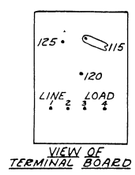
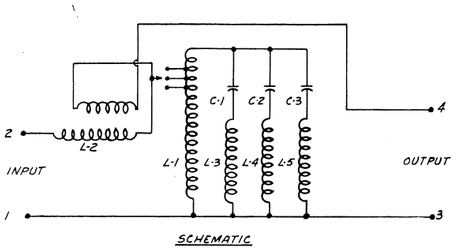


Figure 78—Typical Magnification Characteristics
(*M*-442103—*Sub.* 0)





VIEW OF TERMINAL BOARD

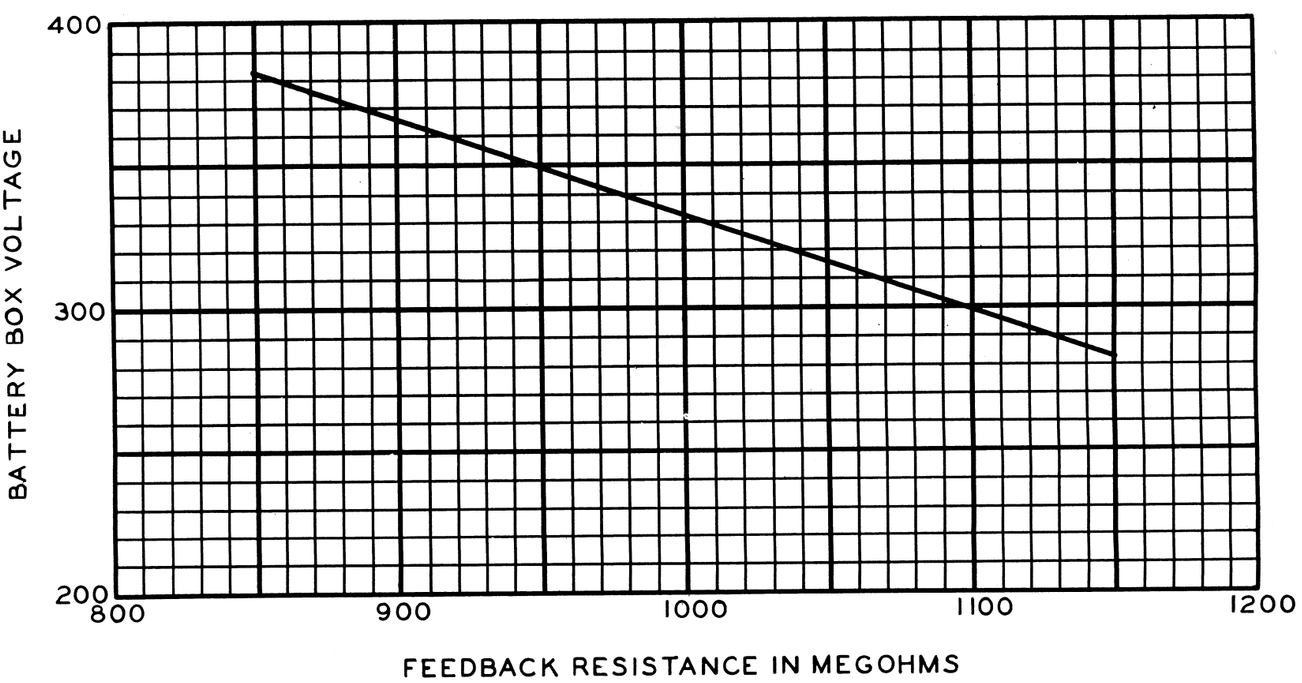


SCHEMATIC

PART	MI	A	B	C	D	E	F	"H" DIA.	J	APPROX WEIGHT	CATALOG NUMBER	RATING
1	MI-12959-B	26½ +1/8	24⅜ +.0 -1/16	23½	12 5/16 +1/8	10 11/16 +1/8	8 15/16	3/4	4¾	165	696380	50 CYC.-1.0 KVA. 95 TO 130 VOLTS LINE 115/120/125 VOLTS OUTPUT
2	MI-12959-A	26½ +1/8	24⅜ +.0 -1/16	23½	12 5/16 +1/8	10 11/16 +1/8	8 15/16	3/4	4¾	165	696379	50 CYC. 1.0 KVA. 190 TO 260 VOLTS LINE 115/120/125 VOLTS OUTPUT
3	MI-12959	22½ +1/8	21⅜ +.0 -1/16	21	11 1/16 +1/8	10 1/16 +1/8	8¼	10/16	3½	145	696555	60 CYC. 1.0 KVA. 95 TO 130 VOLTS LINE 115/120/125 VOLTS OUTPUT

NOTE - REFERS TO PTS. 1, 2, & 3.
LINES 1 & 3 ARE COMMON - INPUT VOLTAGE ON TERMINALS 1 & 2. OUTPUT VOLTAGE ON TERMINALS 3 & 4 115, 120 OR 125 VOLTS WITH LINK CONNECTION TO CORRESPONDING VOLTAGE ON TERMINAL BOARD.
OUTPUT VOLTAGE VARIATION ±1% AT 1.0 KVA.
OUTPUT VOLTAGE VARIATION ±2% AT 0-1.0 KVA. AT 97% POWER FACTOR. (INCLUDES HARMONIC FILTER)
PURCHASE FROM GENERAL ELECTRIC OR EQUIVALENT.
PEAK OUTPUT VOLTAGE SHALL NOT BE LESS THAN 1.4 TIMES RATED OUTPUT VOLTAGE AT 97% LAGGING POWER FACTOR.

Figure 79—Voltage Stabilizer Outline Drawing (P-719101—Sub. 3)



HIGH VOLTAGE FEEDBACK RESISTANCE
VS
BATTERY BOX VOLTAGE
FOR 50,000 VOLTS OUTPUT FROM HIGH VOLTAGE UNIT

Figure 80—Chart for Battery Box Voltage (M-439401—Sub. 0)

BATTERY BOX LAYOUT

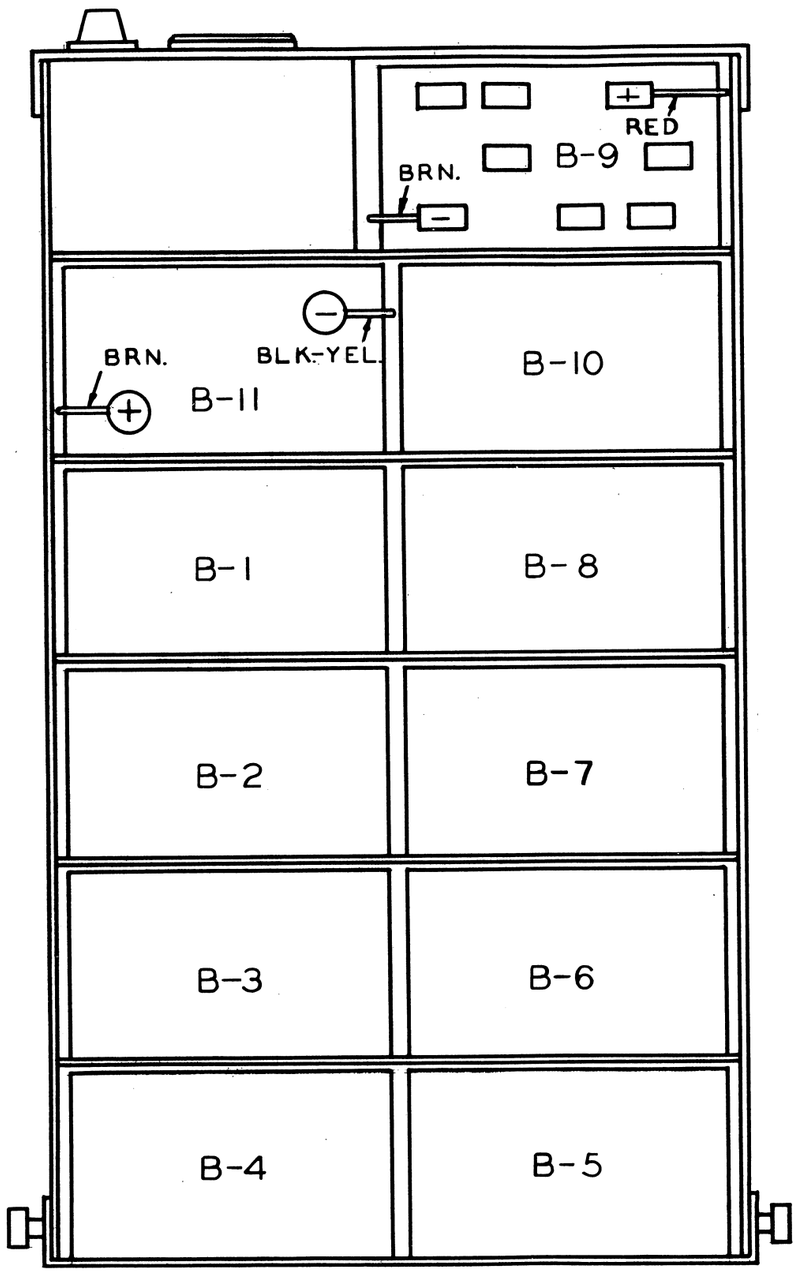


Figure 81—*Battery Box Layout*
(*M*-439402—*Sub.* 0)

TYPICAL VACUUM GAUGE CHARACTERISTICS

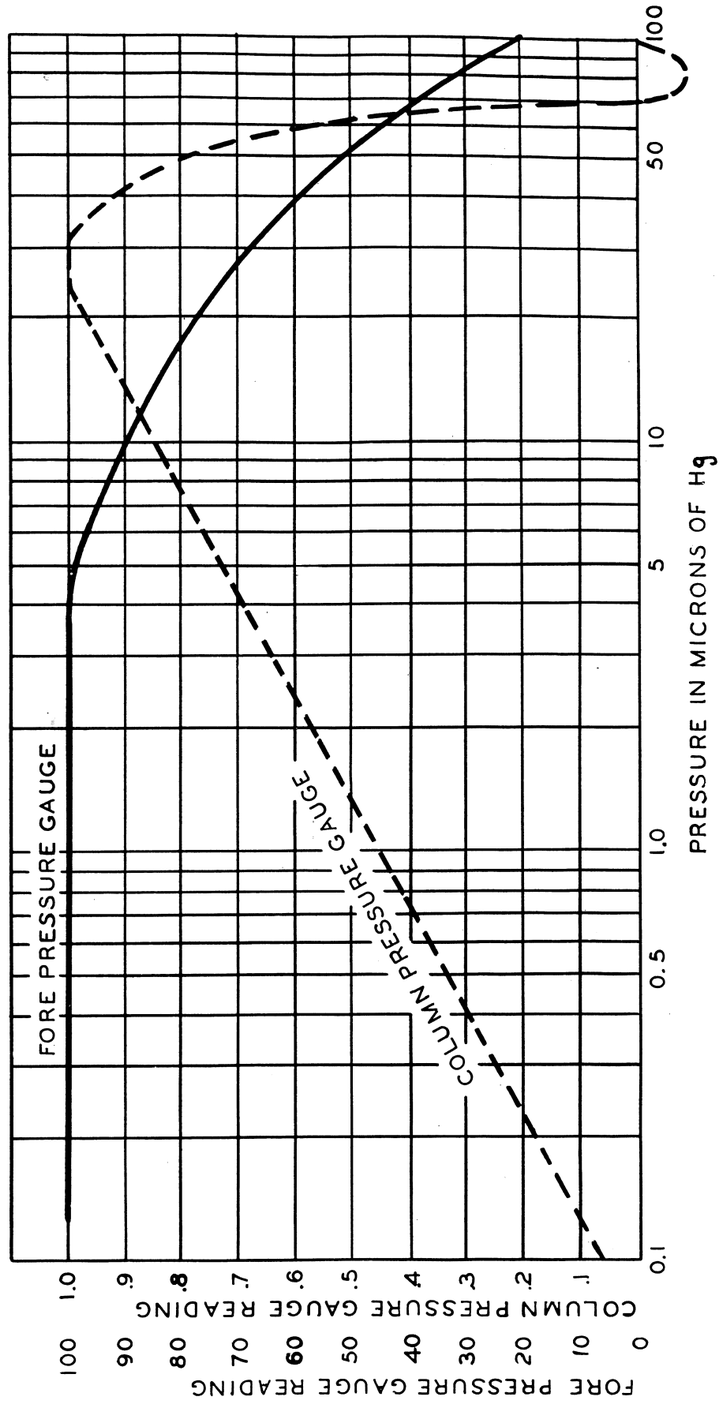
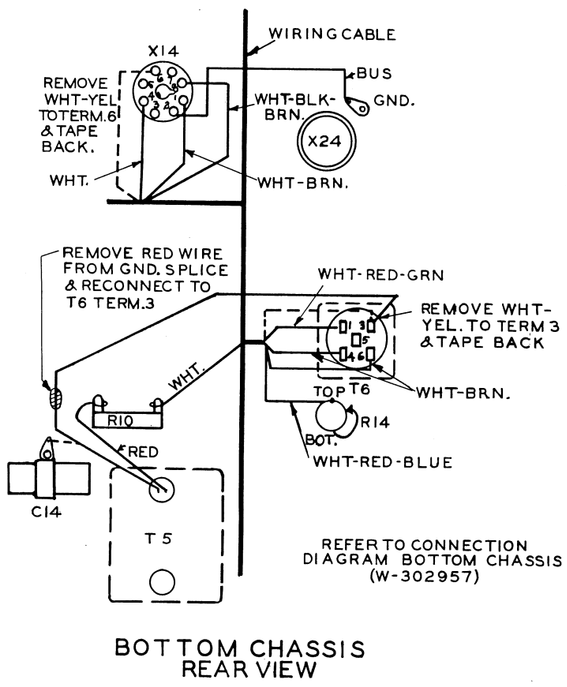
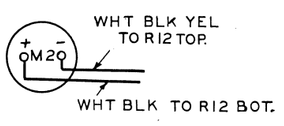


Figure 82—*Typical Vacuum Gauge Characteristics*
(*M*-430559—*Sub.* 0)



BOTTOM CHASSIS
REAR VIEW



INTERCHANGE WIRES TO M2
TO POSITIONS SHOWN

CONTROL PANEL
REAR VIEW
REFER TO CONNECTION DIAGRAM, CONTROL PANEL (W-302959)

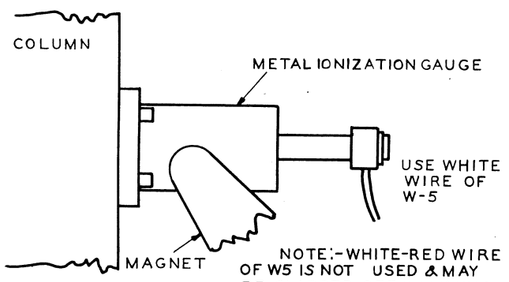
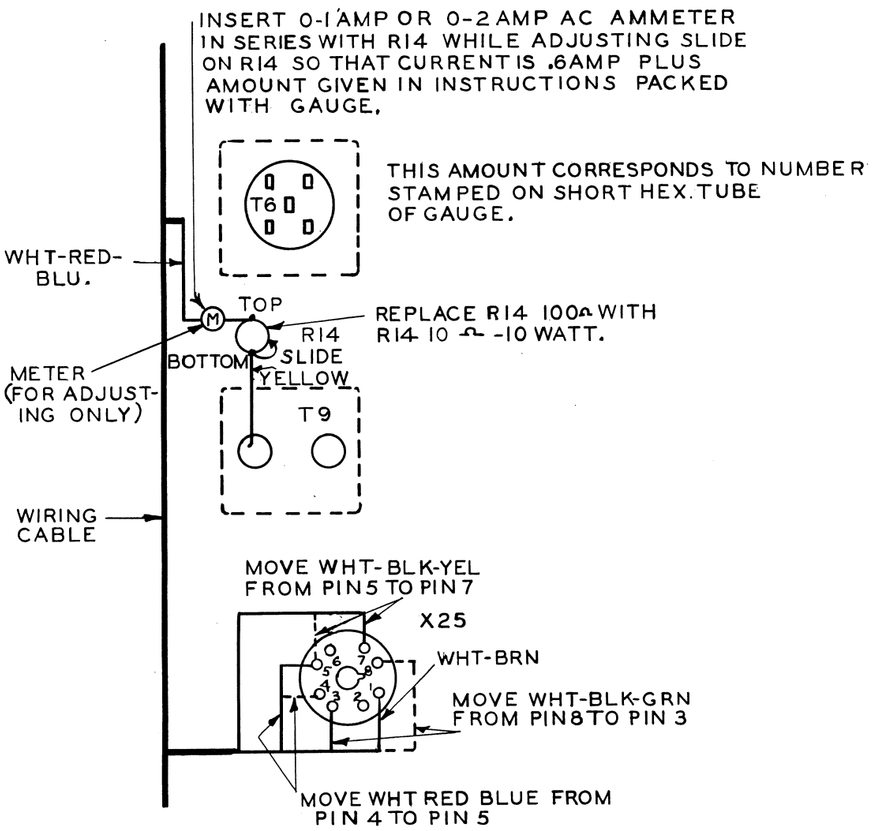


Figure 83—Replacement of Ionization Gauge, Electron Microscope, Type EMU-2A (M-44105—Sub. 0)



BOTTOM CHASSIS, REAR VIEW
REFER TO CONNECTION DIAGRAM W-302957

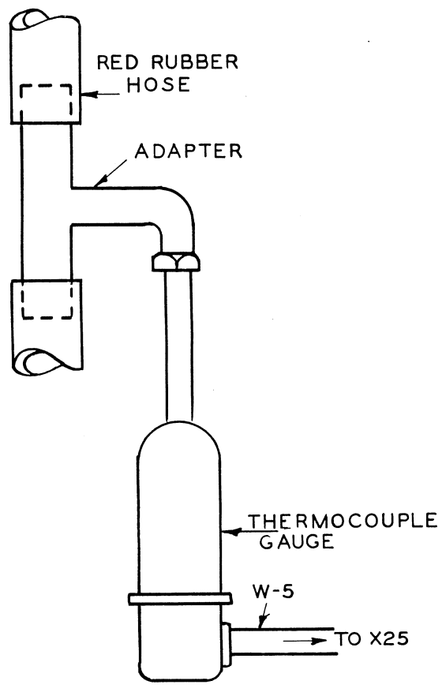


Figure 84—Replacement of Thermocouple Gauge, Electron Microscope, Type EMU-2A (M-44104—Sub. 0)